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INTERNATIONAL SEARCH REPORT

 International application No.
PCT/US98/07360

A. CLASSIFICATION OF SUBJECT MATTER

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US CL : 180/219

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
noneElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,087,108 A (Winchell) 02 May 1978 (02.05.78), figs. 1 and 3.	1-3, 5, 6,, 9-12, 14, 29, 32-34, 42- 60 ----- 4, 7, 8, 13, 15- 28, 31, 35-41, 61- 87

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 4,570,739 US 4,570,739 A (Kramer) 18 February 1986 (18.02.86) fig. 1.	1-3, 5-8, 10, 12, 14, 29, 32-34, 42- 60 ----- 4, 9, 11, 13, 15- 28, 30, 31, 35-41, 61-87
Y	US 5,265,695 A (Piazzi) 30 November 1993 (30.11.93), element 1.	1-87
Y	US 1,951,277 A (Elliotte) 13 March 1934 (13.03.34), element 36.	1-87
Y	US 5,039,121 A (Holter) 13 August 1991 (13.08.91), figs. 1 and 4.	1-87
Y	US 5,388,659 A (Pepe) 14 February 1995 (14.02.95), fig. 2.	1-87
Y	US 5,097,922 A (Stagi) 24 March 1992 (24.03.92), fig. 5.	1-87



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(21) International Application Number: <div style="text-align: right;">PCT/US98/07360</div> (22) International Filing Date: <div style="text-align: right;">14 April 1998 (14.04.98)</div> (30) Priority Data: <div style="display: flex; justify-content: space-between;"> <div> 08/843,423 09/013,322 </div> <div> 15 April 1997 (15.04.97) 26 January 1998 (26.01.98) </div> <div> US US </div> </div> (63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Applications <div style="display: flex; justify-content: space-between;"> <div> US Filed on US Filed on </div> <div> 09/013,322 (CIP) 26 January 1998 (26.01.98) 08/843,423 (CIP) 15 April 1997 (15.04.97) </div> </div> (71) Applicant (for all designated States except US): EMPOWER CORPORATION [US/US]; 25 First Street, Cambridge, MA 02141 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): STAE LIN, David [US/US]; 14 Tappan Road, Wellesley, MA 02181 (US). ULRICH, Nathan [US/US]; 34 Sheep Road, Lee, NH 03824 (US). NIELSEN, Peter [US/US]; 21 Nut Island Avenue, Quincy, MA 02169 (US). WALLACE, David [US/US]; 3		Pine Knoll Road, Lexington, MA 02173 (US). STAE LIN, Paul, H. [US/US]; 82 Myrtle Street #3, Boston, MA 02114 (US). LANG, Jeffrey, H. [US/US]; 22 Weir Hill Road, Sudbury, MA 01776 (US). SCHOONMAKER, James [US/US]; 88 Poplar Street, Watertown, MA 02172 (US). (74) Agent: WALPERT, Gary, A.; Fish & Richardson P.C., 225 Franklin Street, Boston, MA 02110-2804 (US). (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>Without international search report and to be republished upon receipt of that report.</i>

(54) Title: PORTABLE SCOOTER

(57) Abstract

A portable, personal scooter is disclosed which is small, lightweight, and foldable for enhanced portability. A motorized version is controlled by a controller sensitive to platform load, among other things. Brake and suspension systems are shown, as are skids ahead of the rear wheels for navigating road hazards. Advantageous combinations of pivotable bearings and joints enable the scooter to be tilt-steered and easily folded for portage and storage. The arrangement of bearings and pivots provides for several folded configurations. The "half-folded" configuration is partially collapsed and permits the user either to carry it or to tow it on its rear wheels, much like wheeled airport luggage. The "fully-folded" configuration can be the size of a briefcase and easily carried, stored, or shipped. A collapsible brace provides rigidity to the steering shaft while allowing it to be turned for steering and to be tilted laterally. A special wheel suspension mechanism helps the front road wheel pass over an obstacle such as a curb. Wheel braking and suspension systems are also disclosed. Methods of collapsing and transporting the scooter are also disclosed.

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PORTABLE SCOOTERBackground of the Invention

This invention relates to portable scooters, such as are used for personal transportation.

5 By "scooter", we mean a vehicle with a single front wheel steered by handlebars and at least one rear wheel (all of the wheels having a diameter no more than about one-third of the wheelbase of the vehicle) and a broad foot platform extending across the vehicle between
10 the front and rear wheels. Power has been applied to scooters in various ways. Commonly an internal combustion engine, or other type of engine, of less than about 5 brake horsepower drives a rear wheel. In some cases, a seat is provided rearward of the platform. A
15 typical wheelbase of such a vehicle is a meter or so, and the wheels are approximately 30 centimeters or less in diameter. In some vehicles, two rear wheels are provided, and the rear axle and attached motor assembly does not tilt; the rider does so as the single front
20 wheel, its steering handle, and the platform of the vehicle tilt laterally together. For larger scooters, the steering handle and platform or seat are sometimes constrained from tilting laterally. Generally, speed control is provided by hand- or foot-controlled
25 mechanisms which are directly linked to a carburetor or, for electric motors, to a current-control circuit. Typical sizes and weights of vehicles of this type can make portage or storage difficult, and their storage volumes generally exceed 0.1 cubic meters.

30 Summary of the Invention

In general, the invention provides a portable scooter which is light enough to be easily carried, small enough to carry on a bus or pull into a store, while

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being at the same time generally safe, fun, and easy to use.

According to one aspect of the invention, the scooter has a platform constructed to support a rider thereupon, a front wheel, two rear wheels and a graspable steering handle. The rider may be supported upon the platform either in a standing or sitting position, for instance. The front wheel is steerable and rotatable about a front axle connected to the platform. The steering handle is attached to the front axle to steer the axle and is adapted to be tilted (for example, as the rider leans during turns). The rear wheels are rotatable and are arranged to, in combination with the front wheel, support the platform upon a road surface, such that the platform remains substantially parallel to the road surface as the steering handle is tilted. In this regard, the platform of the scooter does not lean or tilt with the handle as a rigid body, as in traditional, two-wheeled scooters. The handle, however, is free to be leaned or tilted with the rider.

In some embodiments the steering handle is attached to the front axle so as to tilt the front axle when the handle is tilted, thereby providing some camber steer. The scooter may also have a torsion member or other spring connecting the steering handle and platform and adapted to bias the steering handle to a neutral-steer position.

Some embodiments of the scooter have a structure adapted to be folded (or otherwise collapsed) for portage. The scooter may also have a graspable grip arranged adjacent the front wheel for raising the front wheel and manually towing the scooter upon the rear wheels. The grip may be on the platform or at the lower end of the handle.

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In some cases the steering handle includes an elongated steering column extending upward from the front axle during use. The column has an upper section, a lower section attached to the front axle, and a hinge
5 connecting the upper and lower sections for lowering the upper section of the column toward the front wheel from a locked, upright steering position, for portage. The upper section of the column may include a graspable handlebar offset from the longitudinal, rotational axis
10 defined by the column.

In some cases the column has at least two elongated, overlapping sections arranged to be telescoped and locked to adjust the length of the column.

Some embodiments of the invention also have a
15 brace pivotably connected to the steering column and attached to the platform to support the column in its upright position. The brace is a structural member, and is preferably attached to the column and platform at points spaced apart from the lower end of the column for
20 rigidity.

In some embodiments the platform has forward and rearward sections joined at a platform hinge, such that the platform is constructed to be folded about the platform hinge.

25 Preferably the scooter is adapted to, when folded, fit within a rectangular parallelepiped having an overall volume of about 3000 cubic inches (more preferably, within a rectangular parallelepiped having an overall volume of about 2700 cubic inches). In one instance, the
30 scooter is adapted to, when folded for portage, fit within a rectangular parallelepiped of dimensions 14 inches by 8 inches by 24 inches (35.5 by 20.3 by 61.0 centimeters).

Some embodiments also have a motor adapted to
35 drive at least one wheel. The motor is preferably

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adapted to produce a maximum power of between about 0.1 and 10 brake horsepower (more preferably between about 0.2 and 2 brake horsepower).

Some motorized versions of the scooter have a loading sensor responsive to platform loading, and a drive controller responsive to a signal from the loading sensor. The controller is adapted to inhibit the driving of the wheel driven by the motor in the absence of a platform loading within a predetermined, acceptable range. The acceptable range may include all values below a predetermined maximum acceptable loading, all values above a predetermined minimum acceptable loading, or all values between predetermined minimum and maximum loadings.

Some motorized versions of the scooter have a speed sensor responsive to scooter speed, and a drive controller responsive to a signal from the speed sensor and adapted to inhibit the driving of the wheel by the motor above a predetermined scooter speed. Some versions have both a speed sensor and a platform sensor, the drive controller being responsive to signals from the speed sensor and platform loading sensor and adapted to inhibit the driving of the wheel by the motor in the absence of a speed and loading combination within a predetermined acceptable combination range. The acceptable combination range may be defined, for instance, by a platform loading between about 50 and 300 pounds and a vehicle speed less than about 20 miles per hour.

Some embodiments include a motor temperature sensor responsive to motor temperature, and a drive controller responsive to a signal from the motor temperature sensor and adapted to limit electrical current applied to the motor in response to the signal.

Some motorized versions of the scooter have a drive controller adapted to control electrical power to

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the motor, and an electrical connector in electrical communication with the drive controller and exposed to be accessed externally for diagnostic communication.

The scooter is preferably constructed to weigh, 5 without rider, less than about 80 pounds (more preferably, less than about 40 pounds, and even more preferably, less than about 35 pounds).

Some embodiments have a rear suspension connecting the rear wheels to the platform and including an elastic 10 element for storing energy during suspension deflection. The rear suspension may include a rear trailing arm having a first end attached to the platform forward of the rear wheels and a second end supporting the rear wheels. The rear suspension may also have a torsion bar 15 having one end attached to the first end of the rear trailing arm and another end attached to the platform, such that the torsion bar is twisted during suspension jounce.

Preferably, either the front wheel or the rear 20 wheels, or both, are non-pneumatic for low rolling resistance.

Some embodiments have a front suspension connecting the front axle to the platform and including an elastic element for storing energy during suspension 25 deflection.

In some embodiments, the scooter has a rear brake with a brake lever extending upward from the platform, the lever arranged to be stepped upon by the user to activate the brake. The rear brake, in some cases, is 30 adapted to engage both rear wheels when the user applies a downward force to the brake lever.

The scooter preferably has a wheel base between the front and rear wheels of between about 25 and 40 inches and wherein the platform has a width, in a 35 direction perpendicular to the wheel base, of between

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about 9 and 18 inches, for good stability. In these embodiments, the platform should have an upper surface (upon which the rider stands) between about 3 and 7 inches from the ground.

- 5 In some embodiments, the platform has an angled lower skid extending downward from the platform forward of the rear wheels and arranged to intercept, and lift the rear wheels over, an upwardly extending road hazard. The skid has, in some constructions, a plurality of
10 rollers rotatably attached to the platform forward of the rear wheels, and a belt mounted about the rollers and defining a lower skid surface. The belt is adapted to be rotated about the rollers when struck by a road hazard.

- In some versions of the scooter, the front axle
15 includes a single spherical bearing enabling rotation about both a first axis (for steering) and a second axis, perpendicular to the first axis, for lowering the steering handle.

- The scooter may also have a tow hitch attached to
20 the platform and adapted for connecting a trailer.

 In some cases, the platform extends rearward over the rear wheels such that, in a folded condition, the scooter may be balanced upright on end upon the platform and rear wheels.

- 25 According to another aspect of the invention, a scooter has a platform constructed to support a rider thereupon and to collapse for portage, a front wheel, at least one rear wheel, and an elongated steering column. By "collapse", we mean fold, contract or otherwise be
30 substantially changed in shape or broken down without being separated into multiple pieces, such that the scooter is more easily transported and/or stored. The front wheel is steerable and rotatable about a front axle connected to the platform. The rear wheel or wheels
35 is/are arranged to, in combination with the front wheel,

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support the platform upon a road surface. The steering column extends substantially vertically from the front wheel to a graspable handlebar and is adapted to be rotated about a substantially vertical axis to turn the front axle. The column is also adapted to be lowered toward the platform from a locked, upright steering position, for portage. By "handlebar" we do not mean to imply that the graspable portion of the steering column must be of any particular shape. The handlebar should provide a comfortable means for the rider to steer the scooter, and should not interfere with the collapsibility of the scooter as the column is lowered.

Some embodiments have two rear wheels, preferably spaced apart laterally across the width of the platform to provide good platform stability. The platform, in some cases, extends rearward over the rear wheels such that, in a folded condition, the scooter may be balanced upright on end upon the platform and rear wheels.

In some embodiments, the scooter has a brace pivotably connected to the steering column and attached to the platform to support the column in its upright position. The brace may have one or more of the following features: the brace is pivotably connected to the platform and includes a brace hinge to enable the brace to be folded about the brace hinge to lower the steering column; the brace has one end adapted to slide rearward along the platform as the steering column is lowered; the brace has upper and lower portions adjustably connected at a lockable joint, such that the effective length of the brace is adjustable to vary a tilt angle of the steering column with respect to the platform. The steering column may be connected to the front wheel through a pivotable joint, with the brace either configured to be lengthened or manually disconnected to enable the steering column to be tilted

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forward of the front wheel for towing. In one configuration, the brace has a first end firmly attached to the steering column at a point spaced from the pivot point, the brace extending from the column to a second
5 end firmly attached to the platform to rigidly support the column in its upright position.

In some embodiments the platform has forward and rearward sections pivotably connected at a platform hinge, such that the platform is constructed to be folded
10 about the platform hinge from an extended position to a collapsed position for storage. Preferably, the graspable handlebar is offset from the substantially vertical axis of the column and aligned with the center of gravity of the scooter with the platform in its
15 collapsed position, to facilitate carrying or towing the scooter by the handlebar.

In some cases, with the platform folded about the platform hinge, the rear wheel or wheels is/are arranged at one end of the folded scooter, opposite the steering
20 column, for towing the scooter upon the rear wheel or wheels by the steering column.

In some embodiments, the steering column has upper and lower sections pivotably connected at a column hinge, such that the column is foldable about the platform in
25 its collapsed position. In some other configurations the column has at least two elongated, overlapping sections arranged to be telescoped and locked to adjust the length of the column (for instance, for transporting the scooter or to accommodate users of different heights).

30 In some instances, the platform has a forward section and a rearward section slidably connected to the forward section to enable the distance between the front and rear wheels to be shortened for portage and/or storage.

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According to another aspect of the invention, a method of collapsing the above-described scooter for portage is provided. The method includes detaching one end of the brace and lowering the steering column toward
5 the platform by rotating the column about the pivot point until the column lies directly against the platform. In such instances the detached brace does not inhibit or limit the rotation of the column toward the scooter.

In some instances, the platform defines a slot for
10 receiving the detached brace as the steering column is lowered against the platform.

In some cases, the method includes detaching both ends of the brace, thereby removing the brace completely.

According to another aspect, the invention
15 provides a method of transporting the above-described scooter. The method includes unlocking the pivotable joint between the steering column and the platform (for instance, by removing a brace), folding the platform about the platform hinge to its collapsed position,
20 pivoting the steering column toward the platform such that the rear wheels are disposed at an end of the collapsed scooter opposite the handlebar (folding the platform and pivoting the column may be done simultaneously or in either order), attaching the
25 steering column to the platform (for instance, by engaging a latch) to maintain the scooter in its collapsed condition, and rolling the collapsed scooter upon its rear wheels while lifting and holding the distal end of the steering column (either by grasping the
30 handlebar or another grip provided for such purpose).

The above features and aspects can be combined in several advantageous combinations to provide many advantages which will be apparent from the following specification and drawing.

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Brief Description of the Drawing

Fig. 1 is a side view of a scooter according to the invention, in an unfolded state.

Fig. 2 is a top view of the scooter of Fig. 1.

5 Fig. 3 is a top view of the scooter in a first "side-folded" state, with the handlebars over the platform.

Fig. 4 is a side view of the scooter in a first "side-folded" state, with the handlebars under the
10 platform.

Fig. 5 is a side view of the scooter in a "top-folded" state.

Fig. 6 is a side view of the scooter in a second "side-folded" state.

15 Fig. 7 is a top view of the scooter in a second "side-folded" state.

Fig. 8 is a top view of a second embodiment of the scooter, in a "top-folded" state.

Fig. 9 is a side view of the second embodiment, in
20 a "top-folded" state.

Fig. 10 is a side view of the second embodiment in an unfolded state.

Fig. 11 is a top view of the second embodiment in an unfolded state.

25 Fig. 12 is a side view of a third, full-folding embodiment of the scooter, in an unfolded state.

Fig. 13 is a side view of the third embodiment, in a first "top-folded" or "half-folded" state.

Fig. 14 is a side view of the third embodiment, in
30 a "full-folded" state.

Fig. 15 is a side view of the third embodiment, in a second "top-folded" state.

Fig. 16 is a side view of a fourth, full-folding embodiment of the scooter, in an unfolded state.

35 Fig. 16a is a side view of the scooter in a "wagon mode."

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Fig. 17 is a side view of the fourth embodiment, in a "top-folded" or "half-folded" state.

Fig. 18 is a side view of the fourth embodiment, in a "full-folded" state.

5 Fig. 19 is a side view of a platform-telescoping version of the scooter of Figure 16, in a "full-folded" state.

Fig. 20 is a top view of the scooter of Fig. 16, illustrating footbrakes and other features.

10 Fig. 21 is a top view of the scooter of Fig. 16, with further options and attachments.

Fig. 22 is a top view of a fifth embodiment of the scooter with a single rear wheel.

15 Fig. 23 is a bottom view of the scooter of Fig. 16, with the addition of two casters.

Fig. 24 schematically illustrates the various bearing options which define an array of scooter configurations with the platform connected to the steering column.

20 Fig. 25 schematically illustrates the various bearing options which define an array of scooter configurations with the platform connected to the front wheel axle.

25 Fig. 26 is a table describing the scooter configurations defined by the bearing options of Figs. 24 and 25.

Fig. 27 is a front view of the spherical bearing assembly of the front wheel of the scooter configurations of Fig. 25.

30 Figs. 28A and 28B illustrate the function of a front wheel retracting mechanism useful for crossing large obstacles.

Fig. 29 illustrates an adjustable suspension and braking mechanisms for the rear wheel of a scooter.

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Fig. 30 is a side view of a skid with a slidable skid belt.

Fig. 31 is a bottom view of the skid of Fig. 30.

Fig. 32 is a side view of an alternative skid embodiment.

Fig. 33 schematically illustrates the electrical system of the scooter.

Fig. 34 schematically illustrates the interaction between the control system of the scooter and the user.

Fig. 35 illustrates in detail the lower level control mechanism of Fig. 34.

Fig. 36 schematically illustrates the electrical drive system of the scooter.

Fig. 37 graphically depicts an acceptable operating envelope of acceleration and velocity for a scooter.

Fig. 38 depicts a flow diagram of a control system for the scooter.

Fig. 39 depicts an alternative embodiment of the scooter of Fig. 16.

Fig. 40 depicts the scooter of Fig. 39 in a half-folded condition.

Fig. 41 depicts the scooter of Fig. 39 in a fully folded condition.

25 Description of Embodiments

In a first embodiment of the scooter, shown in Figs. 1 through 7, the steering and folding mechanism principally involves three separate bearings defining three axes of rotation. In a second embodiment, shown in 30 Figs. 8 through 14, the three rotational degrees of freedom are enabled by a single three-axis spherical bearing. In a third embodiment, shown in Figs. 16 through 23 and 27, rotation about the three axes is provided by a spherical bearing and one single-axis

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bearing. Figs. 24 through 26 present additional bearing configurations for achieving the desired tilt-steer performance.

Referring to the first embodiment, illustrated in Figs. 1 and 2 in its unfolded configuration, the user platform 4 of a scooter 2 is supported by two rear wheels 8 and one forward steered wheel 12, all of which contact the roadway 10. Platform 4 remains roughly parallel to the road for all steering angles and thus provides good balance for the rider, who stands on platform 4 while holding the handlebars 24. The platform is close to the ground (about 2 to 8 inches, preferably about 3 to 7 inches) and wide enough for the user to spread his/her feet apart laterally (about 9 to 18 inches, preferably about 12 to 14 inches), with a wheel base between front and rear wheels of between about 25 to 40 inches, for stability and to avoid pitching the user forward or backward during a spill. The shape of the platform precludes user weight distributions which might tip the platform, and permits the user to easily and safely step off when stationary or moving at reasonable speed.

Steering can be accomplished by twisting handlebars 24 about a vertical axis, much like the way a bicycle can be steered. The handlebars 24 are connected to the front wheel 12 by a two-piece telescoping steering shaft comprising a lower shaft 16 and an upper shaft 20, one of which slides inside the other, the visible joint 22 preferably being near the middle. This telescoping action can be set to a variety of positions by locking detent or lever 28, and can accommodate both folding and the user's desire to raise or lower the handlebars for comfort. Steering torque is transmitted from lower shaft 16 to front wheel 12 by a fork 32 rotatable within collar 36, which is attached rigidly to a front fender 40. Fork 32 can slide vertically within collar 36 to provide a

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short suspension stroke cushioned by spring and shock absorber combination 44. Vibration isolation of handlebar 24 is provided, in some instances, by an additional spring and shock absorber combination located, 5 for example, within telescoping shaft 20 (see, for instance, handlebar spring and shock absorber combination 290 in Fig. 20). The lower surface of platform 4 has skids 60 located directly in front of rear wheels 8 so that when hitting low curbs or potholes the platform is 10 lifted by the wedge angle of skids 60, shielding rear wheels 8 from the full force of the road transition and preserving rider stability. The wedge angle θ_w of skids 60 is preferably between about 5 and 20 degrees.

Half-folding to a "top-folded" configuration is 15 accomplished by releasing and resetting a locking detent or lever 28 and telescoping upper shaft 20 and lower shaft 16 to a desired length, then releasing and rotating lower steering shaft 16 about a pivot 48 until it reaches the position shown in Fig. 5. Once in a "top-folded" 20 state, the steering shaft is held in place by attachment 84 which connects the handlebars to the rear of platform 4. The separation between handlebars 24 and platform 4 can be increased, to 4 to 8 inches or more, to permit the half-folded scooter to be balanced upon its rear end and 25 stored. Alternatively, the handlebar-platform separation can be made nearly zero so that the half-folded scooter can be balanced on end by support from the rear fenders 64, for instance at points 68, and rear wheels 8 at point 73; balance points 68 and 73 are, in some arrangements, a 30 few inches apart. The user can tow the scooter on its rear wheels 8 by pulling the scooter by a front handle 80, illustrated in Fig. 5, or carry it by a side handle 56, illustrated in Figs. 1 and 5. Side handle 56 is located approximately over the center of gravity of the

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scooter so that, when carried, the scooter hangs straight and does not rub against the user's leg.

The scooter is accelerated and braked by pressing the accelerator 72 and brake 76 levers or buttons.

5 Alternatively, auxiliary bicycle caliper brakes can be mounted on the handlebars and connected to a wheel.

A longitudinal (roughly fore-aft) rotational axis is defined by tilt shaft 52 and permits the steering shaft and wheel to tilt laterally in line with the user's
10 body when making sharp turns with significant lateral acceleration. Front wheel 12, front fender 40, and lower steering shaft 16 all tilt together as a substantially rigid body. Tilt shaft 52 is normally provided with stops, not shown, to limit the degree of tilt unless the
15 user applies extra force or releases a detent, and includes a torsion member which biases the front wheel and steering shaft to an upright position.

Figs. 3 and 4 show the scooter in a "side-folded" configuration achieved by rotating tilt shaft 52
20 approximately 90 degrees before or after lower steering shaft 16 is rotated about pivot point 48. In Fig. 3 upper 20 and lower 16 steering shafts are shown telescoped down to fit over platform 4, while upper steering shaft is rotated approximately 90 degrees about
25 its longitudinal axis to enable handlebars 24 to lie flat against the top of platform 4. In Fig. 4 an alternative folded configuration is shown, with the handle beneath platform 4. Both configurations have advantages in particular situations, and the former permits the scooter
30 to be towed easily on its rear wheels 8 by the handle 82. In this flat-folded configuration the scooter can also be easily carried by side handle 56.

Figs. 6 and 7 illustrate a second "side-folded" configuration, in which fender 40 and wheel 12 are
35 pivoted about the longitudinal axis of the scooter via

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tilt shaft 52, but upper steering shaft 20 remains unrotated about lower steering shaft 16. Handlebars 24 can be positioned entirely on one side of the scooter as shown in Figure 6, or centered (not shown), with upper steering shaft 20 parallel to user platform 4. In this second "side-folded" configuration, the scooter can be towed by front handle 86. Handle 86 is connected to fender 40 via a second handle portion 90, at a right angle to handle 86, to enable the scooter to also be towed in a "top-folded" state, as shown, for instance, in Fig. 5. In this second "side-folded" state, the scooter can be balanced on its back end for storage, supported by the two rear wheels 8 and handlebars 24. Alternatively, it can be set on its side, supported by handlebars 24 and lower steering shaft 16. Side handle 56 can be located on either or both sides of platform 4.

In a second embodiment, illustrated in Figs. 8 through 11, the three rotational bearings associated with tilt shaft 52, collar 36, and pivot 48 of Fig. 1 are replaced with a single spherical bearing 94. Fig. 10 illustrates, in side view, how the two rear wheels 8 and the front steered wheel 12 support platform 4 over the roadway. Fig. 11 illustrates how spherical bearing 94 is attached to platform 4 from the side, and how front wheel 12, fender 126, upper steering shaft 20 and lower steering shaft 16 can all move together over a total range of steering angles of approximately 90 degrees. Lower steering shaft 16 is held at a fixed caster angle, the angle between lower shaft 16 and roadway 10, by angular brace 122. The length of brace 122 is adjustable by turning turnbuckle 106, which can alternatively be located at either end of brace 122. Brace 122 must be strong enough to absorb loads induced by road obstacles or the user, and is foldable about brace hinge 114 to assume the position shown in Fig. 9. Brace 122 is

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coupled to lower shaft 16 by ball joint 110, which permits steering rotation and lateral tilting of front wheel 12, but with the caster angle fixed. The opening 98 in the platform 4 provides necessary clearances for steering motion. When half-folded in the "top-folded" configuration of Fig. 9, the scooter can be towed upon its rear wheels 8 by lifting the front of the scooter by handle 80, which also functions as a bumper.

These configurations can further be disassembled at various points, using appropriate latches or simple fasteners, to be small enough to carry or ship easily.

A full-folding, third embodiment with a spherical bearing is illustrated in Figs. 12 through 15, and is similar to the embodiment of Figs. 8 through 11, except that the steering shaft has three parts: a lower part 17, an upper part 23, and a shaft extension 21, which connects to handlebars 24. Instead of sliding together, lower part 17 and upper part 23 are coupled at shaft hinge 19. Shaft extension 21 slides relative to upper part 23 to provide height adjustment for handlebars 24. Similarly, the platform is divided into a forward platform 154 and a rear platform 162, which are joined at platform hinge 166 and which have a slightly lapped joint 159 to avoid pinching. The brace 134 is linked by lockable brace hinge 150, which can be released to fold in a direction indicated by arrow 142 as the handle is folded backwards, or as the forward platform folds forwards in a direction indicated by arrow 174, into the configurations shown in Figs. 13 through 15. The lower surface 158 of forward platform 154 is contoured to nest within contours on the lower surface of rear platform 162. The rear axle is preferably split, enabling front wheel 12 to nest between the two rear wheels 8 when folded. Alternatively, the forward and rear platforms can have different lengths, or the front wheel can be

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removed before folding, to permit the use of an unsplit axle. Two-wheeled embodiments are foldable in a similar fashion by locating the two wheels slightly offset laterally and not locating the motor between them. Brace
5 134 is connected to lower part 17 by lateral hinge 130 which permits the handlebars to steer the front wheel, and lower and upper parts 17 and 23 to tilt laterally as the user leans right or left. When the scooter is in the "top-folded" or "half-folded" configuration of Fig. 13,
10 it is towable by handle 24 as it rolls on rear wheels 8. Appropriate latches may be employed to hold the scooter folded.

An alternative "top-folded" configuration is shown in Fig. 15, with tow handle 146 at the front, and shaft
15 extension 21 slid within the upper part 23 to fit within the bounds required for towing on rear wheels 8.

Fig. 14 illustrates the fully folded configuration, in which the scooter has been folded further, from the state shown in Fig. 13, by rotating
20 upper part 23 about shaft hinge 19 so that handlebar 24 rests against rear wheel 8.

Fig. 16 illustrates a fourth embodiment, in which spherical bearing 220 permits front wheel 12 and steering shaft 216 to be steered laterally up to a predetermined
25 maximum angle, while front wheel 12 is free to rotate about a separate axle 224 supported by bearings. The same spherical bearing 220 also permits the elevation of the steering shaft 216 (the tilt angle between shaft 216 and forward platform 154, illustrated by arrow 174) to be
30 adjusted to user preference by sliding upper brace 226 with respect to lower brace 230, the length of the brace being adjusted and fixed by brace lock 234. The effective length of the combination of braces 226 and 230 is shortened to facilitate compact folding or extended
35 (or the brace disconnected) to permit the user to pull

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the scooter behind him like a wagon. This particular towing mode is referred to as "wagon mode", and is illustrated in Fig. 16A. The brace attachments 235 and 237 permit the desired lateral tilting and rotation of the steering shaft 216. Alternatively, the tilt angle (arrow 174) can be adjusted by use of a fixed-length or variable-length brace and either a slidably disposed attachment 235 which can be moved along and be adjustably fixed to steering shaft 216, or a slidably disposed attachment 237 which can be moved fore/aft along the forward platform 154. The steering shaft has three slidably disposed elements 216, 208, and 204, which connect to handlebars 24 by a handlebar attachment 200. Handlebar attachment 200 provides a convenient location for a sensor and display mechanism 201, which connects to the brake handle 76, the accelerator lever 77, and the display 201 (see also Fig. 17). The slide release and securing mechanism 215 permits middle steering shaft 208 to be slid into lower steering shaft 216 for folding purposes, and to be locked in one or more extended positions, depending on user height and preference. Slide release and securing mechanism 207 performs a similar function for steering shafts 208 and 204. Catch 199 attaches to the end of forward platform 154 near joint 159 to prevent the folded steering shaft elements 204, 208, and 216 from sliding apart, and to keep upper steering shaft 204 locked to forward platform 154 when the scooter is fully folded.

Rear platform 162 is attached to forward platform 154 by shaft 166, which also permits the rear platform 162 to fold toward the forward platform 154 in the direction indicated by arrow 170, opening joint 159 in the top surface of the platform, which is lapped above to minimize pinching between forward platform 154 and rear platform 162. In some arrangements, this joint also

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contains a shock absorbing material to permit a slight rotational flexing of joint 159 when the scooter is temporarily loaded. Shaft 166 and its bearings and latches are sufficiently stiff to prevent any significant
5 unintentional folding of the platform in the direction indicated by arrow 170. Rear wheels 8 are driven by a motor drive train 256, which is controlled via brake handle 76 and accelerator lever 77, as communicated through a wire 212 in the steering shaft and a wire 238
10 in the platform. Wire 212 is spring-loaded to compress without binding within the steering shaft when the shaft is collapsed. To provide extra braking power beyond that available from drive train 256, a mechanical brake pad 250 is actuated by the user stepping on fender 254 and
15 thus pressing a connected brake pad 250 against the top surface, or an inner surface, of rear wheel 8. Hinge 259 (Fig. 18) permits rear fender 254 and brake pad 250 to flex downward against rear wheel 8 for braking. To facilitate standing the scooter on its rear end when
20 folded, support structure 255 either extends rearward of rear wheel 8 at all times, or is deployed when the scooter is fully folded. One or more rear lights 257 are provided for signalling or other purposes.

Storage space 246 is provided for a cable
25 associated with recharging port 744 (see Fig. 33) which plugs into typical wall electrical outlets for recharging. Space 242 is for general storage, and space 245 contains a bag 249 for enclosing the folded scooter so it may be carried or stored indoors. Optional doors
30 enclose the storage spaces.

Fig. 17 illustrates the half-folded configuration of the scooter embodiment of Fig. 16. Forward platform 154 and rear platform 162 are shown folded together about shaft 166, while spherical bearing 220 enables lower
35 steering shaft 216 to fold back against forward platform

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154. Upper brace 226 and lower brace 230 (see Fig. 16) have been retracted, folded together, or moved aside to permit this configuration. Middle steering shaft 208 and upper steering shaft 204 remain extended in this
5 configuration to enable the scooter to be pulled behind the user on rear wheels 8 like airport luggage. An optional luggage carrier 263 can be unfolded from the top surface of rear platform 162, or installed from elsewhere, to permit luggage to be carried in this
10 configuration. Luggage carrier foot 265 permits the scooter to be balanced on its end, even when luggage is aboard. In the absence of luggage carrier 263, balance is provided for standing the scooter on its rear end by support structure 255, or by rear wheel 8 in combination
15 with rear fender 254.

Fig. 18 illustrates the fully folded configuration of the embodiment of Fig. 16. In this view the steering shaft has been telescoped by sliding steering shaft elements 204, 208, and 216 together, and locking
20 handlebar attachment 200 to the forward platform by catch 199. The folded scooter can be carried by grasping either shaft 166, handlebars 24, or a side handle 258, which is located roughly above the center of gravity of the scooter. Also shown in this view are power output
25 port 748 and I/O test port 726 (see also Fig. 33).

Fig. 19 illustrates an alternate folding mechanism in which forward platform 154 slides within rear platform 162 to shorten the combined platform. A second sliding member may be located between forward platform 154 and
30 rear platform 162 to provide a three-piece telescoping unit and a longer scooter wheelbase. As in previous embodiments, spherical bearing 220 enables steering shaft 216 to be folded against rear platform 162. The steering shaft elements telescope together, as in Fig. 18, and are
35 secured together and to rear platform 162 by a latch 262.

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The folded scooter can be carried by side handle 258 located over the center of gravity, or by handlebar 24. The folded scooter, as carried by side handle 258, should not extend more than about 24 inches below the side
5 handle for ease of carrying. Preferably, for ease of portage and storage, the scooter should be constructed to be folded to fit within the bounds of a parallelepiped having an overall volume of less than about 3000 cubic inches (more preferably, less than about 2500 cubic
10 inches). The scooter illustrated is foldable to fit within a small space represented by the dashed rectangle 1002, which is one side of a parallelepiped of dimensions 14 inches by 8 inches by 24 inches, having a volume of about 2700 cubic inches. The compact size of the folded
15 scooter allows for stowing the scooter in the trunk of a car, or on a boat or bus, for instance.

Referring to Figs. 16 and 20, the steering shaft (comprising elements 216, 208, and 204) is secured to handlebar 24 via a spring-shock absorber assembly 290,
20 and to forward platform 154 by means of spherical bearing 220 (hidden behind lower steering shaft 216). Lower steering shaft 216 is also connected to front wheel 12 by axle 224. Spherical bearing 220 is connected to forward platform 154 by support arm 278. Brake lever 294 and
25 accelerator lever 298 are connected to the electrical motor drive train 256 via wire 212. Controls are provided on both sides of handlebar 24, together with an optional mechanical brake actuating mechanism. An opening 306 in forward platform 154 provides space for
30 front wheel 12 to steer right or left. Mechanical braking can be actuated by stepping on one or both rear fenders 254, which are supported by hinges 259 and optionally connected by brake bar 274 which actuates both the right and left brakes when stepped on. Forward

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platform 154 is joined to rear platform 162 at joint 159, which is shown covered by a non-skid foot mat 286.

To permit easier manual propulsion of the scooter by foot, it is useful to have a low platform height of about 3 to 7 inches, which can be accommodated by lowering the platform between lines 302a and 302b, leaving a higher platform in the motor area. Optional mechanical or electrical brake actuators 282 are provided in or on the platform. Vibration isolation of handlebar 24 is accommodated by spring and shock absorber 290.

Fig. 21 illustrates optional attachments such as a luggage support 310, a seat 330, an arm rest or user support bar 326, a mechanical hand brake 334, a bent handlebar 322 which extends more toward the rider, a trailer hitch 338, a trailer 342 (supported by two or more rear wheels 358, and optional forward wheels, not shown). Trailer 342 is shown with a lower golf bag or luggage hitch 346, an upper golf bag support 354, and a golf bag 350 for carrying golf clubs 362.

An accelerator lever 318 and a brake lever 314 control the speed. More than one of each of these controls can be provided; the polarity can also be reversed. A light 366 provides illumination of the road in front of the scooter in order to facilitate evening and night use and to make the scooter more visible to the operators of other vehicles.

Fig. 22 illustrates further options. A lower fairing 366 and a middle fairing 370 are added to the lower and middle steering shafts, respectively. To permit the fairings to fold, middle fairing 370 is secured to the top of the middle steering shaft by an attachment 386 so that the middle fairing can slide down over lower fairing 366 when the steering shafts are telescoped together. The fairings are preferably streamlined by bending them backward along creases 368.

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The top edge 404 of lower fairing 366 typically remains behind the lower edge of middle fairing 370.

An optional single rear wheel configuration is illustrated in Fig. 22, with the rear wheel located under a rear fender 390 which, when stepped upon, functions as a mechanical brake by pivoting on hinge 394 and pressing a brake pad against the rear wheel. This configuration provides more space 398 on the rear platform for the user's feet or for luggage. Lateral stability is provided by optional outrigger wheels 378 supported by casters 382 (mounted to the underside of the platform). An optional horn 400 and light 401 are also shown.

Referring to Fig. 23, optional outrigger wheels 378 provide additional platform stability. Front wheel 12 and two rear wheels 8 support forward platform 154 and rear platform 162, which are joined by shaft 166. Shaft 166 is fixed to forward platform 154 by support bearings 408, and to rear platform 162 by support members 416. Lower steering shaft 216 supports front wheel 12 by front axle 224. The central support 412 of rear platform 162, with its support cross arm 464, also supports a torsion bar 460 which provides spring suspension to rear wheels 8 by suspension arms 456, which in turn support the rear wheels on rear axles 452. One or both rear axles 452 are driven by a gear train 448 and motor 432, powered by a motor control and power electronics unit 444 which receives energy from batteries 468 via a wire 428. The gear train 448 utilizes spur gears or other appropriate gearing configurations, including planetary gears housed partly or entirely within a rear wheel, perhaps together with motor 432. To keep the ends of torsion bar 460 and suspension arms 456 from striking the lower surface of the rear platform, shock absorbers 436 are provided. A forward platform support 472 is positioned to straddle and nest with the rear platform support 412 in the half-

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folded and fully-folded configurations. Skids 420 protect the wheels from low curbs or potholes which otherwise might strike rear wheels 8 too high on the wheels for the wheels to roll over them. These skids are
5 preferably sloped at an angle to horizontal of 5 to 20 degrees so that the scooter is lifted, causing the wheels to strike the obstacle closer to their contact points, permitting the suspension system and wheel to roll over the obstacle without throwing the rider forward from the
10 scooter.

Fig. 24 suggests many of the ways bearing are arranged, in various embodiments, to provide for scooter steering and folding. Front wheel 12 is supported by front axle 526, and rear wheel (or wheels) 8 is supported
15 by rear axle(s) 518. The wheels ride on road surface 480 and support the scooter platform 488, which in turn supports the user. A steering shaft 484 joins handlebars 24 to the front axle 526 via a brace bearing 494, a folding bearing 498, and a tilt bearing 502. Front roll
20 bearing 506 and rear roll bearing 514 determine how the user platform 488 tilts. A brace 492 is folded and adjusted by means of one or more of brace bearings 494, a brace adjustment bearing 522, and a lower brace bearing 510. Each bearing permits motion primarily about some
25 combination of the x, y, and z axes indicated by coordinates 501, with the x direction defined as the direction of forward motion of the scooter. An optional flex bearing 485 permits the handle to be folded toward a seated user at a comfortable fixed angle, or to be held
30 rigidly in a straight position.

Fig. 25 illustrates bearing configurations for a scooter with platform 488 connected directly to front axle 526. Bearings 498, 502, and 506 of Fig. 24 are replaced by a single spherical bearing 526.

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The table of Fig. 26 indicates the principal axes of rotation of the bearings of Figs. 24 and 25, assuming the scooter is moving in the x direction and all turning angles are very small. Scooters A through H correspond to the configuration of Fig. 24, while embodiments I and J correspond to Fig. 25. The column labelled "Lateral Tilt" indicates whether the user and steering shaft tilt laterally together with the entire scooter when turning (Y for "yes"; N for "no"). For each scooter, the bearings are indicated as either rigid (R), non-existent (N), or as providing rotation about either the x, y, or z axes, or a combination thereof.

Referring to the table of Fig. 26 along with Figs. 24 and 25, it will be understood that entry A is the classic two-wheel rigid scooter configuration. Bearings 506 and 514 are rigid (R), and the brace and its bearings 494, 522, and 510 do not exist (N). Front wheel 12 rotates about axle 526 which is oriented in the y direction; bearing 502 supports steering shaft rotation about the z axis; and bearing 498 accommodates folding by allowing upper steering shaft 484 to rotate about the y axis. Entry B has a stable, horizontal rear axle 518, and user platform 488, steering shaft 484 and wheel 12 all tilt about the x axis with respect to rear axle 518 because of bearing 514. Entry C corresponds to a rigid scooter with no steering shaft lateral tilt (thus "N" under Lateral Tilt) or brace 492, but with a steering shaft 484 that folds about the y axis at bearing 498. Such a scooter must have three or more wheels for stability. Entries D, E and F provide for steering shaft lateral tilt by bearing 506 rotating about the x axis, so that the platform 488 remains stable and tied to the Y axis formed by the two laterally displaced rear wheels 8. In entries D and E, bearing 522 provides sliding displacement. Entries D, E and F are but three of

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several possible variations of this option involving different folding and brace mechanisms. Entries G and H are two representative options employing a spherical bearing for bearing 502, which permits steering shaft 484 to tilt laterally, as constrained by brace 492 and its bearings. Bearing 502 can also permit the steering shaft to be tilted backward to suit the user and to permit folding, in which case bearing 506 is either rigid or omitted (in either sense, the bearing is not used for movement). Entries I and J, corresponding to Figure 25, employ a spherical bearing 526 or concentric bearing (see Fig. 27) and therefore do not include bearings 502, 506, 514 or 498.

Referring to Fig. 27, spherical bearing 534 is supported by support arms 530 and is free to rotate about all three axes with respect to bearing pads 538, which are supported by a fork 542. Fork 542 also supports roller bearings 554 which permit front wheel 12 to rotate freely about its axis. The tough, high-elasticity tire surface 562 provides low rolling resistance over hard surfaces. Fork 542 is slidable within the steering shaft 546, and is separated from it by a spring and shock absorber assembly 550 which isolates the steering shaft from front-wheel road vibrations. Front-wheel road vibrations are isolated from the rider by the flexibility and lever arm provided by the forward platform 154 and an optional shock absorber in joint 159 (see Fig. 16).

Figs. 28A and 28B illustrate two states of a mechanism for permitting small wheels, desirable for compact folding, to pass more easily over obstacles such as small curbstones or potholes. Fig. 28A illustrates an implementation on the front wheel of a scooter, although any wheel could be so modified. A wheel 564 is supported on its axle 568 by a fork 576, which can pivot rearward on suspension axle 580 supported by steering shaft 584.

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The platform 586 of the scooter is coupled to the steering shaft by a spherical bearing 590 (normally hidden). When wheel 564 rolls along a roadway 572 into an obstacle 594 which might ordinarily stop the vehicle,
5 a spring 598 or a flexure spring 602 yields, permitting fork 576 to rotate backward about suspension axle 580, forcing small wheel 606 downward upon the upper surface 620 of obstacle 594. In some situations platform 586 is also lifted, depending on the height of obstacle 594.

10 Once the front suspension is in the collapsed state shown in Fig. 28B, it is returned to its normal state by the rider pulling back on the handlebars sufficiently to reduce the force downward on axle 580 so that the stressed springs 602 and 598 rotate fork 576 to
15 its normal position. Flexure spring 602 is supported at its upper end by steering shaft 584, and at its lower end by fork 576. Spring 598 is supported at its upper end by platform 586, and at its lower end by fork 576. The junctions at one or both ends of spring 598 are ball
20 joints or are laterally flexible to permit normal steering of fork 576.

The static force exerted by springs 602 and 598 in their normal position (Fig. 28A) can be reduced by placing wheel axle 568 forward of suspension axle 580, as
25 indicated by lines 614 and 618. So positioned, the weight of the rider and vehicle downward on suspension axle 580 tends to keep the wheel in its normal position. Additional forward force on fork 576 is provided, if necessary, by springs 602 and 598 to overcome typical
30 harmless rearward forces exerted by the road 572 on wheel 564 and fork 576. To the extent that the axle 568 is rearward of (closer to the rear of the scooter than) suspension axle 580, springs 602 and 598 function as a traditional trailing arm suspension, reducing the effects
35 of road vibrations on platform 586. In this situation,

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additional force must be applied by either one or both of springs 602 and 598 to compensate for the weight of the vehicle plus rider. The axle 610 of small wheel 606 is alternatively secured to steering shaft 584 or platform 5 586, instead of to fork 576. For reduced rolling friction, non-pneumatic wheels (of a low loss, wear-resistant elastomer) are preferred for both front and rear on electric motor-driven scooters.

Fig. 29 is a side view of an adjustable suspension and braking system for a scooter rear wheel 688 (illustrated by outline). Rear wheel 688 rotates on an axle 680, supported by a trailing arm 640 which pivots on one end of a torsion bar 636, the other end of which is rigidly attached to a suspension arm 644. Gearbox 448 15 and motor 432 of Fig. 23 can optionally be incorporated within trailing arm 640. The maximum extension of the trailing arm is limited by an optional, adjustable stop 676, mounted to support 668 which is, in turn, attached to platform 624. The minimum extension of the trailing 20 arm is limited by a shock absorber bump stop 698, which is positioned to prevent wheel 688 from rubbing against platform 624. A preload adjustment mechanism 648, illustrated here as a thumb screw accessible from the top surface of platform 624, permits the preload tension of 25 torsion bar 636 to be increased for heavier riders. Acoustic isolation between trailing arm 640 and the platform is provided by a shock absorber 628 mounted on the torsion bar support 632, which in turn supports the outer end of torsion bar 636 and permits its limited 30 rotation. Additional acoustic isolation between trailing arm 640 and platform 624 is provided by a shock absorber 652 mounted on suspension arm 644. A pressure sensor 653 measures platform loading due to user weight, and is located either above or below optional shock absorber 35 652.

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Additional spring suspension is provided by an adjustable spring 684, which forces trailing arm 640 away from platform 624. The preloaded pressure of adjustable spring 684 is varied by rotating it about its screw-
5 threaded core. Adjustable spring 684 can alternatively be progressive, with a spring constant that appropriately increases with compression, permitting heavier riders to experience stronger average spring constants than lighter riders, albeit with greater average spring compression.
10 Furthermore, spring 684 in some embodiments incorporates dissipative elements to reduce the effects of spring resonances. Either or both of torsion spring 636 and adjustable spring 684, with or without other known suspension mechanisms, are optionally employed to provide
15 desired suspension characteristics. Adjustable spring 684 is shown placed in series with a pressure sensor 687, which measures user weight. Tail light 689 provides user safety at night and also functions as a brake light.

A platform loading sensor (e.g., pressure sensor
20 653 or 687) enables the motor controller to prevent use of the scooter if rider weight is too great for product or user safety; for example, if the sensed load were over a predetermined limit of 150 kg, the controller may be configured to instigate passive braking by coupling the
25 motor/generator to a resistive load. Conversely, if the scooter loading were determined to be continuously below a minimum reasonable user weight (such as 20 pounds) for more than a minimum period of time, the brakes may be automatically applied to prevent travel, as a form of
30 "dead-man" switch. The minimum reasonable weight should be set sufficiently low (and/or the time period set sufficiently long) that a user can partially place his or her weight on the pavement to manually propel the vehicle with one foot without triggering the automatic braking
35 function. The motor controller may be configured to

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apply both maximum and minimum weight limits simultaneously.

Fig. 29 also illustrates two mechanical braking mechanisms which press brake pads against rear wheel 688 when the user steps on a brake pedal 620, typically located at the rear edge of user platform 624. A brake arm 660 is supported by a brake axle 664, which is mounted to support 668. Brake arm 660 rotates rearward when brake pedal 620 is pressed downward, forcing a brake pad 696 against wheel 688. A lower brake pad 672 is also shown being pressed against wheel 688 by a pivot arm 694 rotating about axle 692 under load from a pin 656 on brake arm 660 which presses and slides against pivot arm 694. These two illustrated braking mechanisms can be used independently or in combination. The mechanical advantage between the relative displacements of brake pedal 620 and brake pads 696 and 672 is determined by the dimensions of the intervening parts. Mechanical advantages of about 0.5 to about 4 are appropriate for most users who are able to put most of their weight upon the brake pedal. Seated users will generally prefer higher mechanical advantages that require less force on the brake pedal. In general, brake pads 672 preferably approach wheel 688 from the side at the level of wheel axle 680 so that the brake pads do not significantly interfere with the normal vertical movement of the wheel permitted by the suspension system. Power brakes (not shown) can be employed with infirm riders, implemented by electro-mechanical actuators.

Figs. 30 and 31 illustrate an improved skid which is placed in front of any wheel to help lift the wheel over obstacles, such as curbs or potholes, in the road. The skid includes a rotatable belt 704 which reduces the chance for vehicle damage caused by sliding contact with an obstacle. The presence of the belt also reduces the

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magnitude of the maximum loads transmitted into the vehicle frame by converting a portion of the contact energy into elastic deformation energy and belt system kinetic energy. Belt 704 is also much more easily
5 replaced than more expensive, structural chassis components. When an obstacle hits the lower surface of slidable skid belt 704, the vehicle is pushed upward by loads transferred through belt 704 into a belt support 702 and thereby into the vehicle structure 700. Skid
10 belt 704 wraps around a front roller 706 and belt support 702, leaving any slack in the belt to form a loop 708 at the rear of the skid. Belt 704 is free to rotate through belt support 702, which presents a slippery surface to the inner surface of skid belt 704. Roller 706 further
15 reduces friction that would tend to impede the rotation of belt 704, and can be rigidly mounted.

Referring to Fig. 32, an alternative embodiment of a skid has a skid belt 716 which is entirely supported by rollers 712 and 713 mounted on a roller support 710 by
20 axles 714 and 715, respectively. More than two rollers can be employed (or belt supports between the rollers), and skid belt 716 can even be omitted if the lower surface of the skid is not too inclined with respect to horizontal. The strength and tension of skid belt 716
25 must be sufficient to avoid excessive depression of the unsupported belt portion 718 between the rollers when an obstacle is hit.

Referring to Fig. 33, controller 730 includes a computer 724 connected to a memory 723 which includes
30 non-volatile Read Only Memory (ROM) 722 and volatile Random Access Memory (RAM) 720 and Static RAM (SRAM) 721. Computer 724 includes a central processing unit 724a, a clock 724b, and other electronic components 724c as needed to function as a computer. Through Input/Output
35 (I/O) port 726, computer 724 is connected to an external

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I/O bus (for example, a Small Computer System Interconnect (SCSI), not shown). Through I/O port 726 and computer 724, computer programs stored in memory 723 for execution by the central processing unit of computer 5 724 are monitored, tested, and modified. Computer 724 is also directly connected to a back-up battery power unit 728 which provides computer 724 with power to enable computer operation if battery pack 746 fails or in the temporary absence of battery pack 746. Back up battery 10 power unit 728 preferably has a normal life of many years.

Through a multiplexer 734, an Analog to Digital (A/D) converter 732 receives analog signals from either a power electronics unit 740, user sensors 742, or a 15 communication system 738. A/D converter 732 converts these analog signals into digital signals before sending them to computer 724. Computer 724 can also receive digital data directly from multiplexer 734, sensors 742, power electronics unit 740 or communications system 738. 20 Power electronics unit 740 receives signals from motor sensors (not shown) within motor 750, including various temperature, current, voltage, and position sensors (not shown), indicating motor status signals, and transmits these signals through multiplexer 734 and A/D converter 25 732 to computer 724. User sensors 742 include one or more pressure sensors, a mode switch, and a brake and an acceleration throttle.

Computer 724 sends digital signals to a Digital to Analog (D/A) converter 733 which converts the digital 30 signals to analog signals before sending them through a multiplexer 735 to power electronics unit 740, user indicators 736, or communication system 738. Power electronics unit 740 sends the signals received from multiplexer 735 to motor 750 to control the operation of 35 motor 750. User indicators 736 convey information to the

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user and include small flashing lights and acoustic beepers for indicating proper or improper scooter operation, mode changes, range remaining with current battery power, and excess speed. Communications system
5 738 sends information to and receives information from (in other words, communicates with) a corresponding external communications system (not shown). The corresponding communication systems can share motor 750 and battery pack 746 status, speed, throttle, security,
10 speed limits, and other information to permit improved scooter control.

Power electronics unit 740 receives electrical power from battery pack 746 and disburses electrical power to all electronics coupled to the scooter. Battery
15 pack 746 preferably includes rechargeable batteries which do not have to be replaced as often as non-rechargeable batteries. A recharging port 744, configured to connect either to a standard wall outlet or to a standard external battery charger, is electrically connected to
20 power electronics unit 740. When recharging port 744 is connected to an external power source or generator 745, or when the scooter is being electrically braked, power electronics unit 740 recharges the batteries in battery pack 746. An on-board electric generator 745 provides
25 hybrid-electric performance and can include a fuel cell, heat engine, solar cell, or internal combustion engine.

Referring to Fig. 34, controller 774 includes a lower level control mechanism 772 that sends and receives signals to and from motor 750 and measures (or accurately
30 estimates) the actual motor torque, motor angular velocity and change in motor angular velocity, as well as the temperature of motor 750, power electronics unit 740, and battery pack 746. Lower level control mechanism 772 also receives signals from sensors 742 responsive to the
35 actions of the user 760 which involve the controls,

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manual scooter motion changes, weight distribution and total weight. Lower level control mechanism 772 sends this information to an upper level control mechanism 764, also within controller 774, via lines 786.

5 With this information, as well as an input from an optional mode switch 762 indicating scooter mode and a vector A consisting of a set of coefficients ($a_1, a_2, a_3, a_4, \dots$), upper level control mechanism 764 calculates a target torque (T_t), a target motor angular velocity (ω_t),
 10 and a target acceleration or braking rate $(\delta\omega/\delta t)_t$ (in other words, target change in motor angular velocity with respect to time; acceleration). Upper level control mechanism 764 sends this data to lower level control mechanism 772 via lines 792 and indicates which of these
 15 values will control the operation of lower level control mechanism 772 for a next predetermined time period (in other words, clock cycle). This data provides the parameters which determine the operation of lower level control mechanism 772 and, therefore, the operation of
 20 motor 750.

In lower level control mechanism 772, the desired motor current in an excited winding is

$$i_t(t) = (I_{\max}) * (T_t) / T_{\max},$$

where

25 T_{\max} = maximum torque, and

I_{\max} = maximum motor current,

provided the magnitude of $i_t(t)$ never exceeds I_{\max} . When T_t exceeds T_{\max} ,

$$i_t(t) = (I_{\max}) * [\text{sgn}(T_t)].$$

30 In implementation, T_{\max} depends on motor and motor drive capabilities and is represented by vector coefficient a_1 . I_{\max} is indicated as coefficient a_4 , and is determined as a declining function of motor and power electronics temperatures, to prevent overheating.

35 The desired torque is given by the equation

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$$T_t = (a_1) * \{1 - \exp[(-a_2) * (\omega_t - \omega) - (a_3) * (\delta\omega/\delta t)_t]\} * [\text{sgn}(\omega_t - \omega)].$$

Here the vector **A** is mode dependent. These modes are described later.

- 5 Referring to Fig. 35, lower level control mechanism 772 receives values for the desired (in other words, target) angular velocity (ω_t), torque (T_t), and angular acceleration (α_t) or its equivalent $(\delta\omega/\delta t)_t$, from upper level control mechanism 764 over lines 792,
- 10 subtracts with a subtractor 794 these desired values from estimates or measurements of actual angular velocity (ω), torque (T), and angular acceleration α or its equivalent $(\delta\omega/\delta t)$, received over lines 793, and causes the motor to respond to any difference 789 between the two sets of
- 15 data to bring the actual values toward the desired values. From subtractor 794, an outer motion Proportional-Integral (PI) controller 788 receives over difference line 789 a velocity error (ϵ_ω) equal to the difference between the desired and actual motor angular
- 20 velocities. Outer motion PI controller 788 tracks this difference as a function of time and outputs a function $d(t)$ which is proportional to the desired torque (T_t). This output function is determined by

$$d(t) = (K_p) * (\epsilon_\omega) + (K_i) * \int [\epsilon_\omega dt],$$

- 25 where

K_p = a gain constant of velocity error, and

K_i = a gain constant of the integral of velocity error.

- An adaptation controller 784 provides an integrator (not shown) within outer motion PI controller 788 with constants K_p and K_i , and an anti-windup limit. The anti-windup limit is a threshold, and if ϵ_ω exceeds this threshold, the integrator stops integrating (that is, the integrator is clamped).

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The output d of outer motion PI controller 788 is passed through a torque limiter 790 which clips the torque signal when it exceeds a (reasonable) threshold set by adaptation controller 784. Adaptation controller 5 784 derives this threshold from the temperature and speed of the motor as well as the state and charge of the battery pack 746. The output of torque limiter 790 is linearized by a linearizer 796 (in other words, linearizer 796 cancels any non-linearity in the relation 10 between motor torque and current). The specific function used by linearizer 796 is matched to the motor and adjusted by adaptation controller 784 in response to motor variations. Adaptation controller 784 periodically adjusts linearizer 796 in accordance with motor 15 temperature. The output of linearizer 796 is the desired level of current (I_t) needed by motor 750 to generate the desired torque (T_t).

The actual level of current 813b available from battery pack 746, dc-to-dc converter 801, and motor 20 driver subsystem 802 is compared to the desired level of current 813a by a subtractor 813, and the difference is sent to a current PI controller 798. As in the case of outer motion PI controller 788, adaptation controller 784 provides K_p , K_i , and an anti-windup limit to an integrator 25 (not shown) within current PI controller 798. The output of current PI controller 798 is sent to and controls dc-to-dc converter 801, controlling the current in motor driver subsystem 802, and, thereby, the torque of motor 750.

30 Motor driver subsystem 802 is controlled by commutation logic 808 which receives signals from a shaft encoder 810 (e.g, an optical encoder or Hall Effect sensor), a low-pass filter bank 806, and a signum function 804. The signum function provides commutation 35 logic 808 with information regarding the sign of the

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desired torque (T_t), while shaft encoder 810 provides commutation logic 808 with the actual position of motor 750. Low-pass filter bank 806 provides commutation logic 808 with the actual speed of motor 750. This information
5 allows commutation logic 808 to properly drive, using motor driver subsystem 802, the three phases of motor 750. Shaft encoder 810 also provides adaptation controller 784 and low-pass filter bank 806 with the position of motor 750. Low-pass filter bank 806 uses the
10 position of motor 750 to estimate the speed of motor 750 and filters the motor armature position and actual torque to produce smoothed estimates of the position, speed, acceleration, and torque of motor 750 (and, thereby, the speed of the scooter). These actual performance
15 estimates are subtracted by subtractor 794 from the new desired performance characteristics (in other words, torque, angular velocity, and acceleration), in the next clock cycle.

Adaptation controller 784 controls the function of
20 the entire lower level control mechanism 772 by taking the estimates of the actual motor torque, position, acceleration, and battery charge, as well as the output from user sensors 742 and temperature sensors 814, and appropriately controlling torque limiter 790, linearizer
25 796, low-pass filter bank 806, and PI controllers 788 and 798. The appropriate control of these systems adjusts the mechanism to account for motor and battery variations due to thermal change, mechanical load, and manufacturing variations. Adaptation controller 784 implements both
30 the speed limit and the change in scooter modes, as well as adjusting the other controllers using, for example, gain scheduling for a given set of estimated motor, battery, and load parameters. Additionally, adaptation controller 784 sends the actual motor torque,

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acceleration, and velocity data to upper level control mechanism 764 via lines 786.

Temperature sensors 814 include a motor temperature sensor, a power electronics temperature sensor, a battery pack temperature sensor, and an outside (in other words, environmental) temperature sensor. If the motor, the power electronics or the battery pack become too hot, they can become damaged and fail. Similarly a permanent magnet motor can fail if the permanent magnets are too cold. The adaptation controller 784 notifies upper level control mechanism 764 of impending failure conditions, such as rising or falling temperatures, and upper level control mechanism 764 notifies the user through user indicators 736.

Referring to Fig. 36, battery-pack 746 provides the power to drive motor 750 through dc-to-dc converter 801 (for example, a voltage-to-current converter). Through appropriate manipulation of the current conversion ratio by the adaptation controller 784, dc-to-dc converter 801 controls the amount of current passing through phase A 824, phase B 825, and phase C 826 motor drive circuits in motor driver subsystem 802. Current sensor 828 provides lower level control mechanism 772 with an estimate of motor torque by providing an estimate of the current passing through the motor. Since

$$T = (K_T) * (I),$$

where

I = the current delivered to the motor through

the current sensor, and

K_T = a known constant generally dependent upon

motor temperature,

this measurement provides an accurate estimate of motor torque (T). In addition, since the conversion ratio used

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by dc-to-dc converter 801 in any cycle is known, this measurement of current sensor 828 also provides adaptation controller 784 with an accurate estimate of the current available from battery pack 746. Voltage sensor 820 provides adaptation controller 784 with a direct measurement of battery pack 746 voltage.

Referring also to Fig. 35, to operate brushless motor 750 motor drive circuits 824, 825, and 826 convey electric pulses to motor 750 which are synchronous to the position (in other words, timing) of the motor. As described above, the position is determined by shaft encoder 810. Using this information, commutation logic 808 drives motor drive circuits 824, 825 and 826 to provide accurately timed electric pulses to motor 750. In-depth discussions on the proper operation of motors can be found in W. Leonhard's Control of Electrical Drives (Springer-Verlag, 1985, Berlin, Germany) and B.K. Bose's Power Electronics and AC Drives (Prentice Hall, 1986, Englewood Cliffs, N.J.).

Referring to Fig. 37, to characterize a particular mode control law (for example, a polynomial, piece-wise linear equation, or table look-up executed by controller 730, Fig. 33), a graph is used to relate the desired acceleration (α_t), sent from upper level control mechanism 764 (Fig. 34) to lower level control mechanism 772, to the actual estimated scooter velocity (V) and to a chosen acceleration metric Q which is positive for acceleration and negative for braking. As one example, Q lies between the values of +1 and -1 and corresponds to the position or stress on the sensor responding to acceleration lever 318 and brake lever 314 in Fig. 21. As shown, for any particular value of Q, the maximum allowed acceleration α_{\max} diminishes slightly with increasing velocity V to a minimum allowed negative acceleration α_{\min} . Safety generally requires a decrease in the allowable

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acceleration as the scooter velocity increases, and equipment considerations generally require a decrease in the allowable acceleration and motor current as the temperature of the motor or power electronics increases.

- 5 When the user presses the accelerator maximally forward ($Q = 1$), the maximum forward safe acceleration is possible if the scooter velocity is negative. As the velocity increases to the speed limit (V_{max}), however, the allowable acceleration diminishes to zero. For
- 10 velocities beyond this speed limit, upper level control mechanism 764 sends lower level control mechanism 772 a negative acceleration command which causes motor 750 to apply reverse torque to the rear axle of the scooter to slow or brake the rear wheel or wheels. The control law
- 15 can be modified to reflect the skill of the user or road condition (typically V_{max} and α_{max} are varied). For example, V_{max} can be temporarily reduced if the torque history of the motor is excessively erratic, indicating a poor road surface or unstable user, and α_{max} can be
- 20 temporarily reduced if the velocity or torque history of the motor becomes unusually erratic following larger accelerations. In addition, depending on a user's skill or preferences, when the scooter is stationary or moving at slow speeds more accelerator pressure might be
- 25 required to achieve a given acceleration to help avoid accidents from unexpected or unnoticed forward motion. This can be accomplished by a non-linear relationship between Q , for example, and α_t , by providing a deadband in the middle of the range of the relationship, where α_t is
- 30 nearly zero. More erratic scooter operation can be followed by an expansion of this low-sensitivity deadband.

The maximum allowed velocity V_{max} can also be made dependent upon the total user weight, where V_{max} goes to

35 zero below some minimum threshold corresponding to either

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an unloaded scooter or to the weight of a child too small to use the device safely. Similarly, if the user weight exceeds a maximum threshold, for example 275 pounds, V_{max} can be set to zero to avoid overloading the motor.

- 5 Fig. 38 illustrates one implementation of the mode control for the scooter of Fig. 16, in which an on-off switch is not required. The controller 730 is normally in a rest state 830 when the scooter is "off", awaiting a clock pulse in test 832. The computer wakes up
- 10 approximately once each second and briefly checks in test 834 whether the wheels are rotating or the brake or accelerator buttons or levers are actuated. If not, it returns to its low power consumption rest state 830; if yes, it goes to a root "on" state 836. If the scooter is
- 15 "locked" by the computer so the motor must remain unpowered, then a test 838 leads to actions 840 which activate indicators 736 (Fig. 33), such as by flashing a light on display 201 once, inviting the user to key in an unlocking combination by pushing the brake 76 and
- 20 accelerator 77 controls in a prescribed series of long and short pulses. If the sequence passes a test 842, then weight sensor 653 or 687 (Fig. 29) is checked in a test 844 to determine if the user weight on the scooter exceeds some minimum (for example, 30 pounds). If yes,
- 25 controller 730 reads the sensors and controls motor 750 and user indicators 736 in accord with the current control mode parameter values set previously in step 870 or in accord with default parameters. If the scooter is unweighted in test 844 for more than T_1 seconds, a test
- 30 848 determines if either the accelerator 77 or brake 76 are being actuated by the user; if not, the user may have stepped off the scooter, and controller 730 actuates braking torques in motor 750. If the scooter remains unweighted, and without any brake or accelerator
- 35 commands, longer than T seconds, controller 730 returns

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from state 850 to rest state 830. If the user is climbing a hill or otherwise using the motor, then the accelerator control 77 will be activated, and so in state 852 controller 730 continues to power the motor, but

5 ensures that wheel acceleration (α) is limited to a modest value that minimizes skidding under suddenly reduced scooter loading when the user steps off the platform to push the scooter or to reduce motor loading on steep hills. Should the scooter be found to maintain

10 zero velocity (V) in test 854 while the accelerator or brake are actuated (test 848), then a test 856 determines the sequence of brake 76 (B) or accelerator 77 (A) commands, seeking a sequence (for example, B-A-B-A) that passes a test 858 and causes user indicators 736 to

15 indicate readiness to accept change-mode commands. A test 862 determines whether brake 76 or accelerator 77 are actuated, and each time the corresponding counters are incremented once in counter 864 or 866, respectively. Each time brake counter 864 is incremented with m no

20 greater than mmax, the number of controller parameters which can be changed (test 868), parameter m is set to state n in a step 870, as determined by the contents of counter 866, and counter 866 is reset to zero. If n is already zero, action 870 is omitted, and the controller

25 returns to state 860. If m exceeds mmax, the counters (864 for m and 866 for n) are reset to zero, and the controller returns to test 844. Parameters m can correspond to, for example, choices of maximum velocity, control law (as exemplified by Figure 37), battery

30 conservation strategy, combination lock complexity (for example, three combinations of different lengths), scooter controller parameters to be displayed immediately on user indicators 736, and others. For each parameter several choices are preferably made available, one of

35 which is selected by the user's choice of index n for

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that value of m . Not shown in Fig. 38 are additional paths from potential trap states back to the root state 836.

Fig. 39 depicts an alternate embodiment of the scooter depicted in Fig. 16. In this embodiment, the telescoping brace has been replaced with a sliding brace 900. The body of sliding brace 900 is comprised of a single member, which neither folds nor telescopes during folding but rather slides into the body of rear chassis 912. To this end, sliding brace 900 is attached to rear chassis 912, by any of a number of means known in the art, so as to allow lateral leaning of the steering column 902. Rear chassis 912 has an appropriate channel 910 running down its longitudinal mid-line in order to accommodate the sliding brace 900 when folded. Channel 910 is shaped in such a way as to not interfere with front wheel 12 in the fully-folded or half-folded configurations.

Further, the three-section steering column shown in Fig. 16 has been replaced with a two-section steering column 902 in Fig. 39. Steering column 902 is comprised of upper column 904 and lower column 906. In this embodiment, upper column 904 includes two parallel columns 903a and 903b, but could easily be a single member as depicted in figure 16. Upper column 904 is slidably disposed with respect to lower column 906 and the sliding is controlled by independent latch 916. Latch 916 is independently controlled to enable the chassis of the scooter to be folded about hinge 914 while not fully collapsing the handle (for instance, for easy towing). For carrying, the chassis may be folded about hinge 914 and the steering column fully telescoped. In addition, independent latch 916 allows the user to adjust the handle height for comfortable riding. In this embodiment, spherical bearing 220 of Fig. 16 has been

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replaced by three independent axis bearings similar to the arrangement depicted in Fig. 1.

The handlebar 24 of Fig. 39 is attached to upper steering column 904 via handle attachment 908. Handle attachment 908 offsets handle 24 from steering column 902 so that larger movements of the handle by the user are required to turn the steering column a given amount, thereby improving stability.

Fig. 40 illustrates the half-folded configuration of the embodiment of Fig. 39. Note that sliding brace 900 is shown disposed fully within channel 910. Handlebar 24 has steering handles 918 and a carrying handle 920. Steering handles 918 are used to steer the scooter while riding, and are placed away from the steering column for ease in applying a steering moment to the column. Carrying handle 920 is used when towing or carrying the scooter and is placed near the column so as to not induce significant moment about the column. Handles 918 and 920 are created by U-shaped handle attachment 908 and handlebar 24 (Fig. 39). Handles 918 and carrying handle 920 may be independently shaped or padded for greater comfort.

Fig. 41 illustrates the fully-folded configuration of the embodiment of Fig. 39. In this figure, carrying handle 920 provides for comfortable carrying by minimizing the moment the user can apply to the folded scooter, thus helping to prevent inadvertent twisting (which can cause the folded scooter to swing into the user's leg while being carried, for instance). In addition, the offset of the handle bars 24 from steering column 920 helps to provide for comfortable carrying by placing handle 920 over the center of gravity 922 of the folded package. This placement of the carrying handle over the center of gravity provides for superior control of the folded package while being carried and allows the

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unit to hang straight down when held, thereby minimizing discomfort by allowing the user to hold the folded unit close to his leg.

Power Sources

5 Although motor 750 (Fig. 34) is described as a battery-driven electric motor, other power sources can alternatively be used, including an internal combustion engine, heat engine, or an electric hybrid motor, provided the appropriate fuel supply is made available.

10 Power Transfer

 Additionally, separate motors can be used to drive each of the rear wheels 8 (Fig. 23) or to drive one forward wheel 12 and one rear wheel 8 or to drive forward axle 224 and/or rear axle(s) 452. Alternatives to gears 15 448 (Fig. 23) can be employed, including direct drive, belts, hydraulic transmissions, or a differential gear box (similar to an automobile). They can have a single gear ratio, or multiple ratios which are switched manually or electrically by command from the controller.

20 Power Output Port

 In addition to the external computer I/O port 726 (Fig. 33) and recharging port 744, an additional external output port 748 can be provided for utilizing the scooter's ability to generate a variety of power signals 25 to drive external equipment for possibly unrelated purposes, for example, a light 401 (Fig. 22).

Temperature

 As an alternative to the various temperature sensors 814 shown in Fig. 35, temperature can be deduced 30 from the operation of motor 750. Using the voltage applied to motor 750 as measured by voltage sensor 820 (Fig. 36), knowledge of the relationship between back-EMF, motor speed and the current applied to motor 750 as measured by current sensor 828, the resistance of the 35 motor windings can be determined. Typically, the motor

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windings are copper which has a predetermined relationship between temperature and resistance. Thus, the temperature of the windings can be estimated when the resistance of the copper windings is known. The
5 temperatures of critical electronic components can also be estimated from measurements of ambient temperatures supplemented by thermal models calculating the time-weighted effect of dissipated heat due to $I^2 \cdot R$, where I is the current through the heated element and R is its
10 electrical resistance. Similarly, the battery temperature can be estimated as a function of battery current over time.

Sensor Locations and Alternatives

The weight sensor 653 shown in Fig. 29 can be
15 located in a variety of positions, including, for example, on platform 4 (Fig. 10). Another weight sensor alternative is pressure sensors 687 which bear the force exerted by adjustable spring 684 (Fig. 29). In addition, scooter orientation sensor 239 (Fig. 18) allows the user
20 to change mode when the scooter is folded or carried by handle 24 or hinge 166 (Fig. 18). Thus, no on-off switch is necessary and the user can signal a desired mode by a predetermined series of scooter motions affecting the orientation sensor or pressure sensor 653.

25 Because different users can impact sensors differently, or the sensor readings can drift, controller 774 (Fig. 34) includes, in some embodiments, an automatic sensor recalibration mechanism. Recalibration is based on an observed range of sensor values during normal use
30 or when the user deliberately exercises critical sensors over their desired dynamic range.

Motorized Wheel Locking

In a "wheels-locked" mode, controller 774 is optionally configured to cause motor 750 to apply reverse
35 or forward torque to one or more wheels as required to

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prevent wheel movement. Mechanical locks, however, have the advantage of not draining the battery. One way to limit the battery drain caused by user stabilization is to significantly limit the stabilizing torques. Another way to reduce power dissipation due only to user stabilization is to apply stabilizing torques only after the scooter rolls an allowable distance, perhaps a few centimeters; such actions alert the user that better balance or a more advantageous position relative to the grade of the terrain is required.

Triggers

Optional triggering signals initiate standardized braking or acceleration protocols, a scooter mode change, locking or unlocking the scooter or brakes, and identifying the scooter owner. Such triggering signals can include: pressure on the accelerator 77 or brake 76; jumping, which reduces weight on the scooter below a predetermined threshold; stamping on the scooter platform once or twice; holding the scooter in specified orientations for predetermined periods; a push backward; a velocity greater than a predetermined threshold; initiation of a recognized braking action; banging the scooter against the ground and detecting this action with accelerometers (for example, two bangs at the correct interval might initiate motion); and tapping the scooter in a prescribed manner sensed by sensors 653 or 687 (Fig. 29).

User Indicators

User indicators 736 (Fig. 34) can include many devices, including simple indicator lights, acoustic signals, and liquid-crystal displays. Useful indications produced by controller 774 include battery voltage and state of charge, likely scooter travel range under available power, low-power warning signals, mode state, scooter velocity, and malfunction indications. One or

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more lights can also be provided for use at night (for example, headlight 401) to illuminate the road immediately ahead of the scooter and as a warning to motorists or others fore or aft (for example, in
5 conjunction with tail-light 689). One or more light sources on the power electronics board can be coupled in desired directions by light waveguides and modulated by liquid crystal or other optical switches, eliminating wires and permitting one light to do the work of several.

10 Observed User Skill

The active control system of the present invention permits speed limits to be placed on the drive motor(s) dependent on the observed braking skill of the user, where more skill authorizes higher speed limits. For
15 example, braking skill can be determined from the observed user stopping distances for various speeds, where observed shorter stopping distances and smoother decelerations merit higher allowed user velocities.

Cooling

20 Power dissipation is typically greatest in the motor and battery pack. This high power dissipation can require cooling, including conduction, radiation, and fluid convection, depending on the overall vehicle construction and use. Reduced loading can also be
25 imposed by the controller when temperature sensors indicate a critical rise in temperature.

Rechargeable Batteries

The life and performance of rechargeable batteries is maximized by proper charging protocols. These
30 protocols can readily be implemented by the controller. The state of battery charge can be estimated from computer-controlled battery-impedance measurements obtained using the power electronics circuits. By knowing the time of day and historic use patterns for the
35 scooter, better compromises can also be made between

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rapid and slow charge protocols. Some batteries perform best if periodically discharged, and automatic deep discharges at night or during storage are also feasible, where the load might be a cooled resistor or the motor.

5 Security Devices

A variety of security devices are easily incorporated into the scooter. For example, the scooter can be automatically immobilized by controller 730 if weight sensors 687 or 653 (Fig. 29) detect a new user
10 weight beyond a predetermined range, or until an authorization code is input using leg and scooter motions (detected by pressure or orientation sensors), switch manipulation, speech recognition, or through a keypad requiring a particular combination input. Rented or
15 leased scooters can refuse recharging unless performed after the receipt of an individual authorization code and/or with a customized recharger. Rented or leased scooters can also cease operation unless an authorization code is periodically received reflecting payments.
20 Authorization codes can be input in many ways, including through switches or through coded audio signals over a telephone to an audio transducer 241 or through a telephone modem 243 (Fig. 18) on the scooter. The same audio transducer can support diagnostic and service
25 functions to update computer programs or allow for scooter customization.

Speech Recognition

Not only can speech recognition be used to input authorization codes, but through speech recognition
30 sensors, comprising a microphone, computer, and speech recognition software, a user can verbally command the scooter. For instance, a user can say "brake" to slow down, "stop" to completely stop, and "faster" to accelerate. Additionally, to prevent the scooter from
35 responding to the speech of others, the controller can be

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programmed to respond to a verbal command only after a predetermined initial verbal or sensor trigger is given followed by verbal commands. In this instance, of course, the necessary computer hardware and software
5 would be installed in controller 730 (Fig. 33).

Safety Devices

A variety of user safety devices can be incorporated in the scooter. For instance, different users of the same scooter might be assigned different
10 speed limits or different default modes and parameters. Built-in driver testing or road characterization programs can be used to establish speed limits or other control parameters. For example, erratic acceleration, braking, weaving, or road vibration can cause controller 730 to
15 lower the speed limit.

Internal Carrying Bag

To facilitate transparent transitions between riding the scooter, traveling in automobiles or public transportation, and walking, a waterproof bag 249 (Fig.
20 16) is provided to enclose the scooter and to protect the user from dirt, rain, or water left on the scooter. The bag can be provided with back straps or a belt to permit easy carriage of the scooter on the user's back or waist. Such a bag can be stored inside space 245.

25 Many combinations of the above-described features are possible, and are within the scope of the invention.

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What is claimed is:

1. A scooter comprising
a platform constructed to support a rider
thereupon;
5 a front, steerable wheel rotatable about a front
axle connected to the platform;
a graspable steering handle attached to the front
axle to steer the axle and adapted to be tilted; and
two rotatable rear wheels arranged to, in
10 combination with the front wheel, support the platform
upon a road surface, such that the platform remains
substantially parallel to the road surface as the
steering handle is tilted.
2. The scooter of claim 1 wherein the steering
15 handle is attached to the front axle so as to tilt the
front axle when the handle is tilted.
3. The scooter of claim 2 further comprising a
torsion member connecting the steering handle and
platform and adapted to bias the steering handle to a
20 neutral-steer position.
4. The scooter of claim 1 further comprising a
spring attached to the handle and the platform and
adapted to bias the steering handle to a neutral-steer
position.
- 25 5. The scooter of claim 1 having a structure
adapted to be folded for portage.
6. The scooter of claim 5 further comprising a
graspable grip arranged adjacent the front wheel for
raising the front wheel and manually towing the scooter
30 upon the rear wheels.

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7. The scooter of claim 5 wherein the steering handle includes an elongated steering column extending upward from the front axle during use, the column comprising

- 5 an upper section,
 a lower section attached to the front axle, and
 a hinge connecting the upper and lower sections
for lowering the upper section of the column toward the
front wheel from a locked, upright steering position, for
10 portage.

8. The scooter of claim 7 wherein the steering column defines a longitudinal, rotational axis and wherein the upper section of the column includes a graspable handlebar offset from the rotational axis of
15 the column.

9. The scooter of claim 7 wherein the column comprises at least two elongated, overlapping sections arranged to be telescoped and locked to adjust the length of the column.

20 10. The scooter of claim 7 further comprising a brace pivotably connected to the steering column and attached to the platform to support the column in its upright position.

 11. The scooter of claim 5 wherein the platform
25 comprises forward and rearward sections joined at a platform hinge, such that the platform is constructed to be folded about the platform hinge.

 12. The scooter of claim 5 further comprising a graspable grip arranged adjacent the front wheel for

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raising the front wheel and manually towing the scooter upon the rear wheels.

13. The scooter of claim 5 adapted to, when folded, fit within a rectangular parallelepiped having an overall volume of about 3000 cubic inches.

14. The scooter of claim 1 further comprising a motor adapted to drive at least one wheel.

15 15. The scooter of claim 14 wherein the motor is adapted to produce a maximum power of between 0.1 and 10 brake horsepower.

16. The scooter of claim 15 wherein the motor is adapted to produce a maximum power of between 0.2 and 2 brake horsepower.

17. The scooter of claim 14 further comprising
15 a loading sensor responsive to platform loading,
and

a drive controller responsive to a signal from the loading sensor and adapted to inhibit the driving of the wheel driven by the motor in the absence of a platform
20 loading within a predetermined, acceptable range.

18. The scooter of claim 17 wherein said acceptable range includes all values below a predetermined maximum acceptable loading.

19. The scooter of claim 17 wherein said
25 acceptable range includes all values above a predetermined minimum acceptable loading.

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20. The scooter of claim 17 wherein said acceptable range includes all values between predetermined minimum and maximum loadings.

5 21. The scooter of claim 14 further comprising a speed sensor responsive to scooter speed, and a drive controller responsive to a signal from the speed sensor and adapted to inhibit the driving of the wheel by the motor above a predetermined scooter speed.

10 22. The scooter of claim 17 further comprising a speed sensor responsive to scooter speed and wherein the drive controller is responsive to a signal from the speed sensor and adapted to inhibit the driving of the wheel by the motor in the absence of a speed and loading combination within a predetermined acceptable combination
15 range.

23. The scooter of claim 22 wherein the acceptable combination range is defined by a platform loading between about 50 and 300 pounds and a vehicle speed less than about 20 miles per hour.

20 24. The scooter of claim 14 further comprising a motor temperature sensor responsive to motor temperature, and a drive controller responsive to a signal from the motor temperature sensor and adapted to limit electrical
25 current applied to the motor in response to said signal.

25. The scooter of claim 14 further comprising a drive controller adapted to control electrical power to the motor; and

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an electrical connector in electrical communication with the drive controller and exposed to be accessed externally for diagnostic communication.

26. The scooter of claim 1 constructed to weigh,
5 without rider, less than about 80 pounds.

27. The scooter of claim 26 constructed to weigh,
without rider, less than about 40 pounds.

28. The scooter of claim 27 constructed to weigh,
without rider, less than about 35 pounds.

10 29. The scooter of claim 1 further comprising a
rear suspension connecting the rear wheels to the
platform and including an elastic element for storing
energy during suspension deflection.

30. The scooter of claim 29 wherein the rear
15 suspension includes a rear trailing arm having a first
end attached to the platform forward of the rear wheels
and a second end supporting the rear wheels.

31. The scooter of claim 30 wherein the rear
suspension further comprises a torsion bar having one end
20 attached to the first end of the rear trailing arm and
another end attached to the platform, such that the
torsion bar is twisted during suspension jounce.

32. The scooter of claim 1 wherein the rear
wheels are non-pneumatic.

25 33. The scooter of claim 1 further comprising a
front suspension connecting the front axle to the

- 57 -

platform and including an elastic element for storing energy during suspension deflection.

34. The scooter of claim 1 wherein the front wheel is non-pneumatic.

5 35. The scooter of claim 1 further comprising a rear brake having a brake lever extending upward from the platform, the lever arranged to be stepped upon by the user to activate the brake.

37. The scooter of claim 35 wherein the rear
10 brake is adapted to engage both rear wheels when the user applies a downward force to the brake lever.

38. The scooter of claim 1 having a wheel base between the front and rear wheels of between about 25 and 40 inches and wherein the platform has a width, in a
15 direction perpendicular to the wheel base, of between about 9 and 18 inches.

39. The scooter of claim 38 wherein the platform has an upper surface upon which the rider stands, the upper surface being between about 3 and 7 inches from the
20 ground.

40. The scooter of claim 1 wherein the platform has an angled lower skid extending downward from the platform forward of the rear wheels and arranged to intercept, and lift the rear wheels over, an upwardly
25 extending road hazard.

41. The scooter of claim 40 wherein the skid comprises

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a plurality of rollers rotatably attached to the platform forward of the rear wheels, and

a belt mounted about the rollers and defining a lower skid surface, the belt adapted to be rotated about
5 the rollers when struck by a road hazard.

42. The scooter of claim 7 wherein the front axle comprises a single spherical bearing enabling rotation about both

a first axis, for steering; and
10 a second axis, perpendicular to the first axis, for lowering the steering handle.

43. The scooter of claim 1 further comprising a tow hitch attached to the platform and adapted for connecting a trailer.

15 44. The scooter of claim 5 wherein the platform extends rearward over the rear wheels such that, in a folded condition, the scooter may be balanced upright on end upon the platform and rear wheels.

45. A scooter comprising
20 a platform constructed to support a rider thereupon and to collapse for portage;

a front, steerable wheel, rotatable about a front axle connected to the platform;

at least one rotatable rear wheel arranged to, in
25 combination with the front wheel, support the platform upon a road surface; and

an elongated steering column extending substantially vertically from the front wheel to a graspable handlebar, the column adapted to be rotated
30 about a substantially vertical axis to turn the front

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axle, and adapted to be lowered toward the platform from a locked, upright steering position, for portage.

46. The scooter of claim 45 comprising two rear wheels.

5 47. The scooter of claim 45 further comprising a brace pivotably connected to the steering column and attached to the platform to support the column in its upright position.

10 48. The scooter of claim 47 wherein the brace is pivotably connected to the platform and includes a brace hinge to enable the brace to be folded about the brace hinge to lower the steering column.

15 49. The scooter of claim 47 wherein the brace has one end adapted to slide rearward along the platform as the steering column is lowered.

20 50. The scooter of claim 47 wherein the brace has upper and lower portions adjustably connected at a lockable joint, such that the effective length of the brace is adjustable to vary a tilt angle of the steering column with respect to the platform.

25 51. The scooter of claim 50 wherein the steering column is connected to the front wheel through a pivotable joint and wherein the brace is configured to be lengthened to tilt the steering column forward of the front wheel for towing.

52. The scooter of claim 47 wherein the steering column is connected to the front wheel through a pivotable joint and wherein the brace is configured to be

- 60 -

manually disconnected to enable the steering column to be tilted forward of the front wheel for towing.

53. The scooter of claim 45 wherein the platform comprises forward and rearward sections pivotably
5 connected at a platform hinge, such that the platform is constructed to be folded about the platform hinge from an extended position to a collapsed position for storage.

54. The scooter of claim 53 wherein the graspable handlebar is offset from the substantially vertical axis
10 of the column and aligned with the center of gravity of the scooter with the platform in its collapsed position.

55. The scooter of claim 53 wherein, with the platform folded about the platform hinge, said at least one rear wheel is arranged at one end of the folded
15 scooter, opposite the steering column, for towing the scooter upon said at least one rear wheel by the steering column.

56. The scooter of claim 53 wherein the steering column has upper and lower sections pivotably connected
20 at a column hinge, such that the column is foldable about the platform in its collapsed position.

57. The scooter of claim 53 wherein the column comprises at least two elongated, overlapping sections arranged to be telescoped and locked to adjust the length
25 of the column.

58. The scooter of claim 45 wherein the platform comprises
a forward section, and

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a rearward section slidably connected to the forward section to enable the distance between the front and rear wheels to be shortened for portage and storage.

59. The scooter of claim 45 wherein the column
5 comprises

a lower portion attached to the front axle, and
an upper portion having said handlebar, the upper
and lower portions pivotably connected at a lockable
joint.

10 60. The scooter of claim 45 further comprising a
motor adapted to drive at least one wheel.

61. The scooter of claim 60 wherein the motor is
adapted to produce a maximum power of between 0.1 and 10
brake horsepower.

15 62. The scooter of claim 60 further comprising
a loading sensor responsive to platform loading,
and

a drive controller responsive to a signal from the
loading sensor and adapted to inhibit the driving of the
20 wheel driven by the motor in the absence of a platform
loading within a predetermined, acceptable range.

63. The scooter of claim 62 wherein said
acceptable range includes all values below a
predetermined maximum acceptable loading.

25 64. The scooter of claim 62 wherein said
acceptable range includes all values above a
predetermined minimum acceptable loading.

- 62 -

65. The scooter of claim 62 wherein said acceptable range includes all values between predetermined minimum and maximum loadings.

5 66. The scooter of claim 60 further comprising
a speed sensor responsive to scooter speed, and
a drive controller responsive to a signal from the
speed sensor and adapted to inhibit the driving of the
wheel by the motor above a predetermined scooter speed.

10 67. The scooter of claim 62 further comprising a
speed sensor responsive to scooter speed and wherein the
drive controller is responsive to a signal from the speed
sensor and adapted to inhibit the driving of the wheel by
the motor in the absence of a speed and loading
combination within a predetermined acceptable combination
15 range.

68. The scooter of claim 67 wherein the acceptable combination range is defined by a platform loading between about 50 and 300 pounds and a vehicle speed less than about 20 miles per hour.

20 69. The scooter of claim 60 further comprising
a motor temperature sensor responsive to motor
temperature, and
a drive controller responsive to a signal from the
motor temperature sensor and adapted to limit electrical
25 current applied to the motor in response to said signal.

70. The scooter of claim 60 further comprising
a drive controller adapted to control electrical
power to the motor; and

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an electrical connector in electrical communication with the drive controller and exposed to be accessed externally for diagnostic communication.

71. The scooter of claim 45 constructed to weigh, 5 without rider, less than about 80 pounds.

72. The scooter of claim 71 constructed to weigh, without rider, less than about 40 pounds.

73. The scooter of claim 72 constructed to weigh, without rider, less than about 35 pounds.

10 74. The scooter of claim 45 further comprising a rear suspension connecting said at least one rear wheel to the platform and including an elastic element for storing energy during suspension deflection.

75. The scooter of claim 45 having a wheel base 15 between the front and rear wheels of between about 25 and 40 inches and wherein the platform has a width, in a direction perpendicular to the wheel base, of between about 9 and 18 inches.

76. The scooter of claim 75 wherein the platform 20 has an upper surface upon which the rider stands, the upper surface disposed between about 3 and 7 inches from the ground.

77. The scooter of claim 45 adapted to, when folded, fit within a rectangular parallelepiped having an 25 overall volume of about 3000 cubic inches.

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78. The scooter of claim 77 adapted to, when folded, fit within a rectangular parallelepiped having an overall volume of about 2700 cubic inches.

79. The scooter of claim 78 adapted to, when
5 folded for portage, fit within a rectangular parallelepiped of dimensions 14 inches by 8 inches by 24 inches (35.5 by 20.3 by 61.0 centimeters).

80. The scooter of claim 45 comprising two said rear wheels in spaced relation to each other, and wherein
10 the platform extends rearward over the rear wheels such that, in a folded condition, the scooter may be balanced upright on end upon the platform and rear wheels.

81. The scooter of claim 45 wherein the platform has an angled lower skid extending downward from the
15 platform forward of said at least one rear wheel and arranged to intercept, and lift said at least one rear wheel over, an upwardly extending road hazard.

82. A personal scooter comprising
a platform constructed to support a rider
20 thereupon and to collapse for portage;
a front, steerable wheel, rotatable about a front axle connected to the platform;
an elongated steering column extending
substantially vertically from the front wheel to a
25 graspable handlebar, the column adapted to be rotated about a substantially vertical axis to turn the front axle, adapted to be lowered toward the platform from a locked, upright steering position for portage, and adapted to be tilted;
30 two rotatable rear wheels arranged to, in combination with the front wheel, support the platform

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upon a road surface, such that the platform remains substantially parallel to the road surface as the steering handle is tilted;

a motor adapted to drive at least one rear wheel
5 and adapted to produce a maximum power of between 0.1 and 10 brake horsepower;

a speed sensor responsive to scooter speed; and

a drive controller responsive to a signal from the speed sensor and adapted to inhibit the driving of the
10 wheel driven by the motor in the absence of a scooter speed within a predetermined, acceptable range.

83. A method of collapsing a scooter for portage, the scooter comprising

a platform constructed to support a rider
15 thereupon and to collapse for portage;

a front, steerable wheel, rotatable about a front axle connected to the platform;

two rotatable rear wheels arranged to, in combination with the front wheel, support the platform
20 upon a road surface;

an elongated steering column pivotably connected at one end to the platform at a pivot point and extending substantially vertically from the pivot point to a graspable handlebar, the column adapted to be rotated
25 about a substantially vertical axis to turn the front axle; and

a brace having a first end firmly attached to the steering column at a point spaced from the pivot point, the brace extending from the column to a second end
30 firmly attached to the platform to rigidly support the column in its upright position; the method comprising detaching one end of the brace; and

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lowering the steering column toward the platform by rotating the column about the pivot point until the column lies directly against the platform.

84. The method of claim 83 wherein the platform
5 defines a slot for receiving the detached brace therein as the steering column is lowered against the platform.

85. The method of claim 83 comprising detaching both ends of the brace.

86. A method of transporting a scooter, the
10 scooter comprising

a platform constructed to support a rider thereupon, the platform having forward and rearward sections pivotably connected at a platform hinge for folding the platform about the hinge from an extended
15 position to a collapsed position;

a front, steerable wheel rotatable about a front axle connected to the forward section of the platform;

two rotatable rear wheels connected to the rearward section of the platform and arranged to, in
20 combination with the front wheel, support the platform upon a road surface; and

an elongated steering column pivotably connected to the forward section of the platform at a lockable joint and extending substantially vertically from the
25 joint to a distal end having a graspable handlebar, the column adapted to be rotated about a substantially vertical axis to turn the front axle; the method comprising

unlocking the joint between the steering column
30 and the platform;

folding the platform about the platform hinge to its collapsed position;

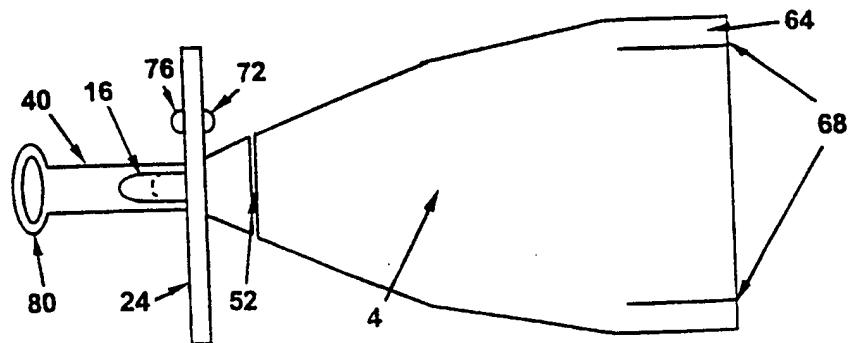
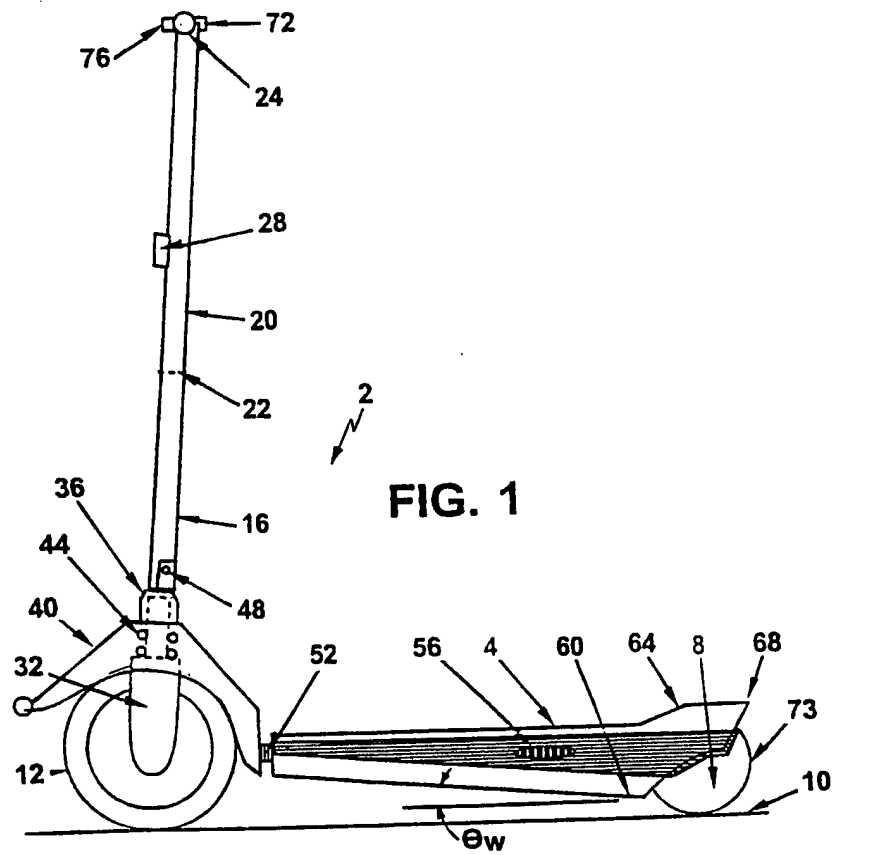
- 67 -

pivoting the steering column toward the platform such that the rear wheels are disposed at one end of the collapsed scooter, opposite the handlebar;

attaching the steering column to the platform to
5 maintain the scooter in its collapsed condition; and
rolling the collapsed scooter upon its rear wheels while lifting and holding the distal end of the steering column.

87. The method of claim 86 wherein the scooter
10 weighs less than about 35 pounds.

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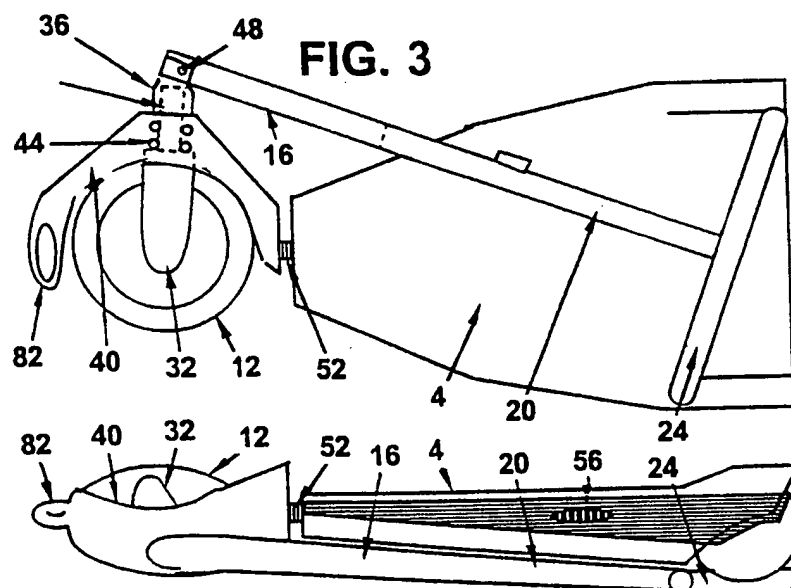


FIG. 4

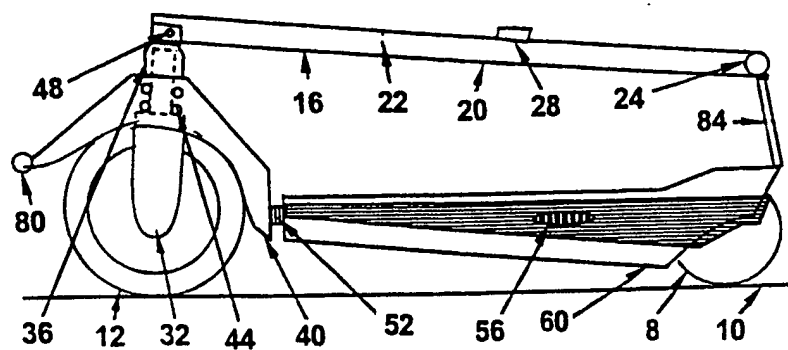


FIG. 5

Figure 6. Side View

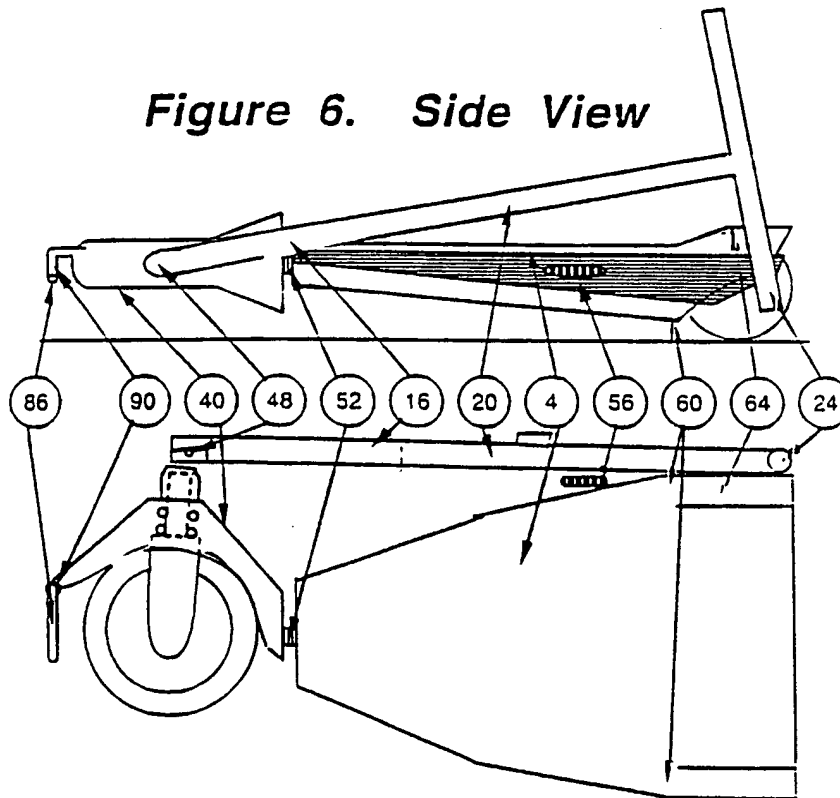


Figure 7. Top View

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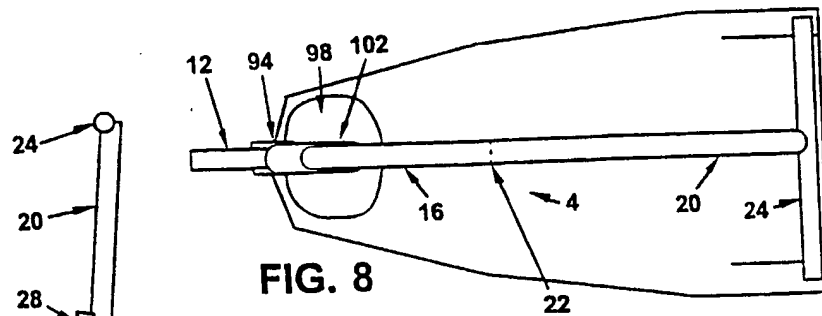


FIG. 8

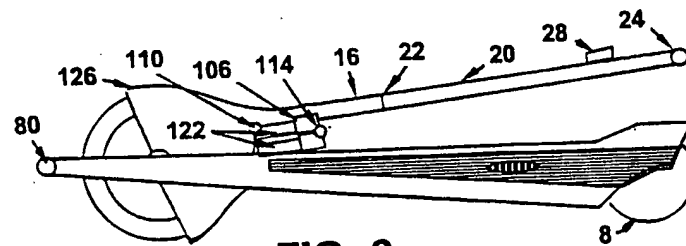


FIG. 9

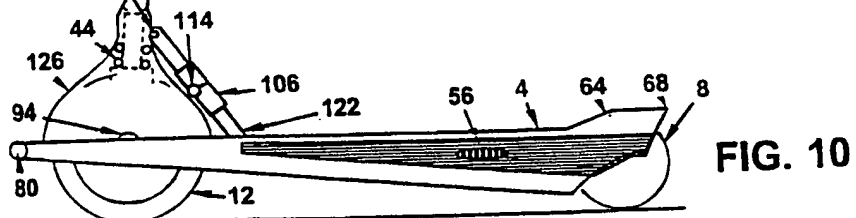


FIG. 10

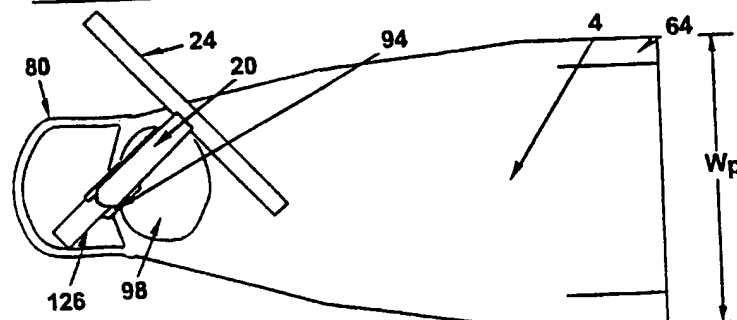


FIG. 11

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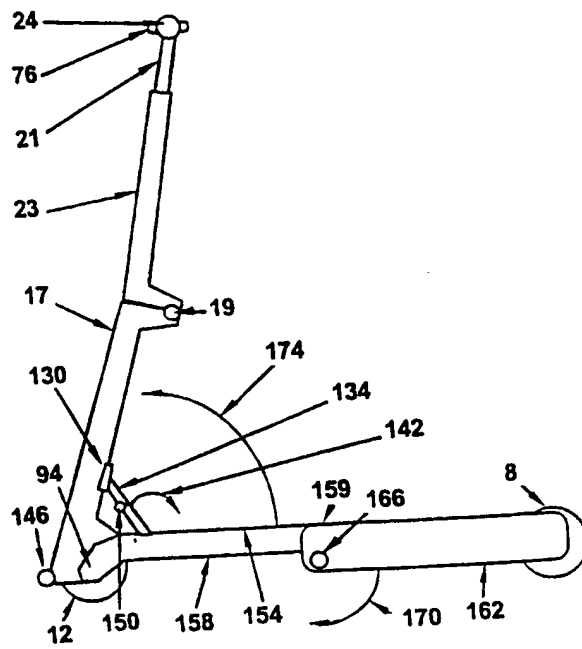


FIG. 12

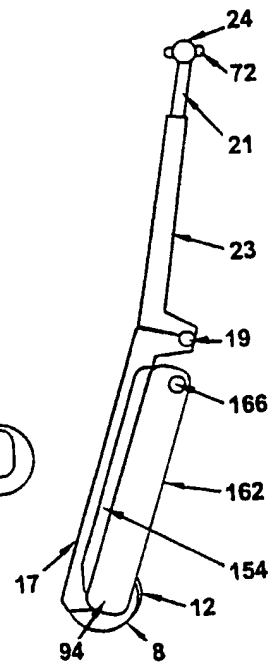


FIG. 13

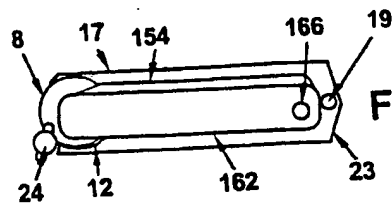


FIG. 14

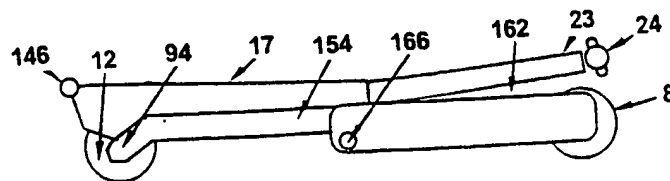


FIG. 15

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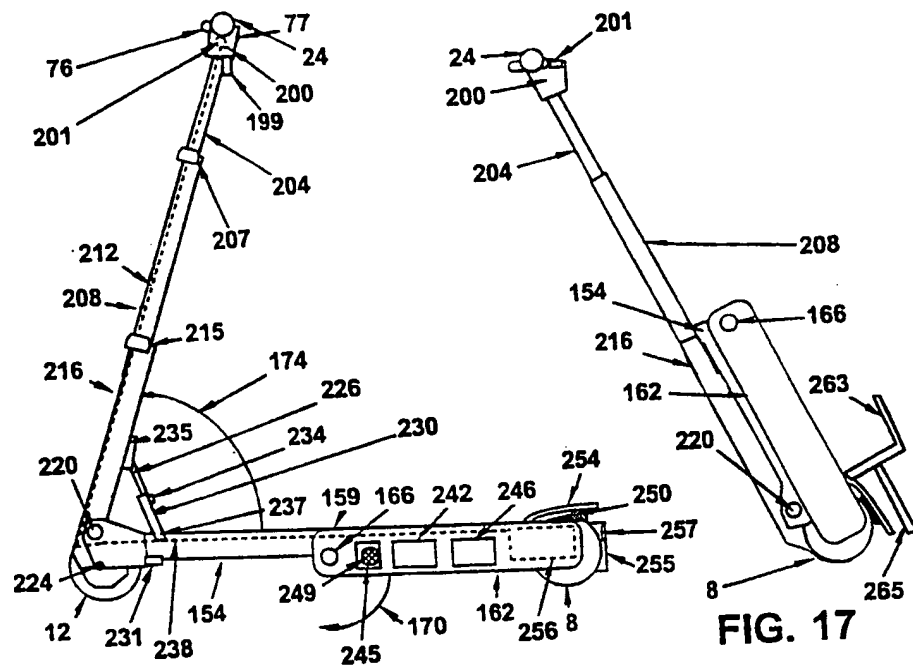


FIG. 16

FIG. 17

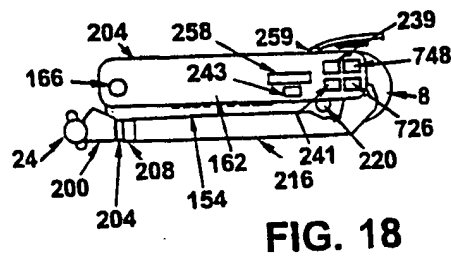


FIG. 18

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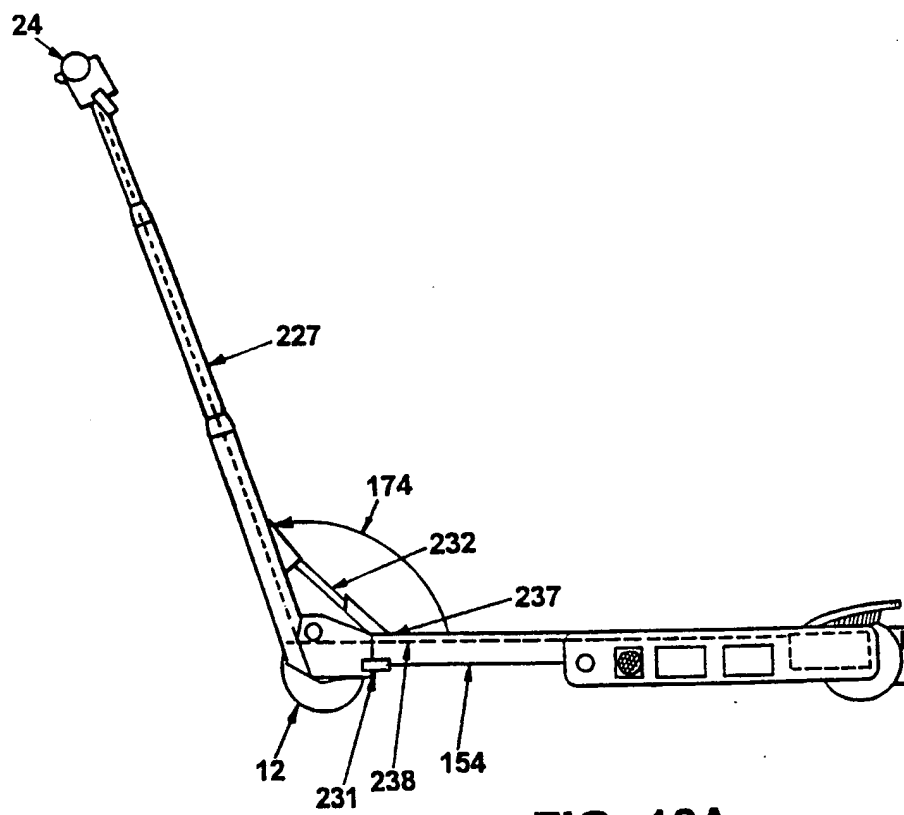
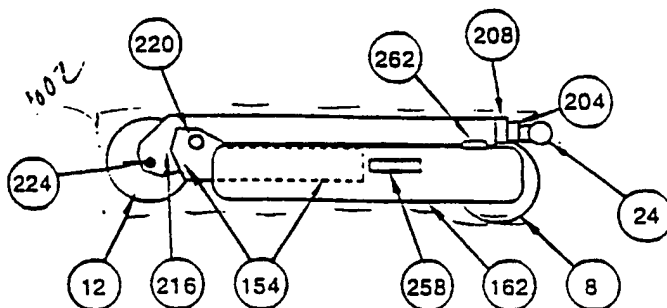
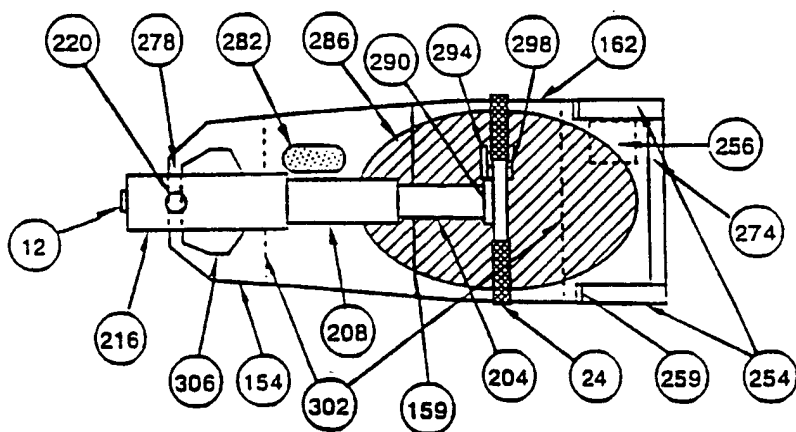
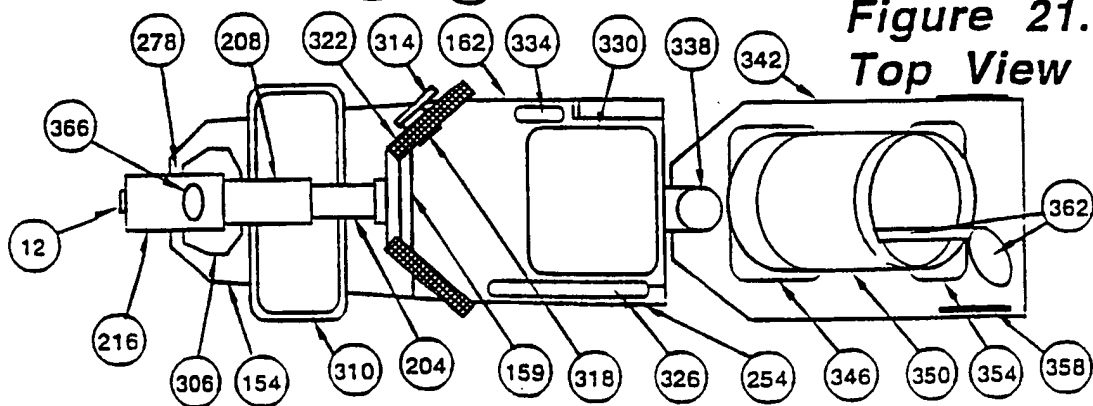


FIG. 16A

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Figure 19. Side View**Figure 20. Top View****Figure 21. Top View**

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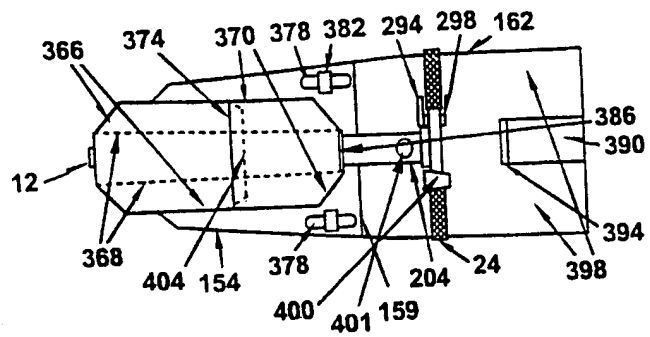


FIG. 22

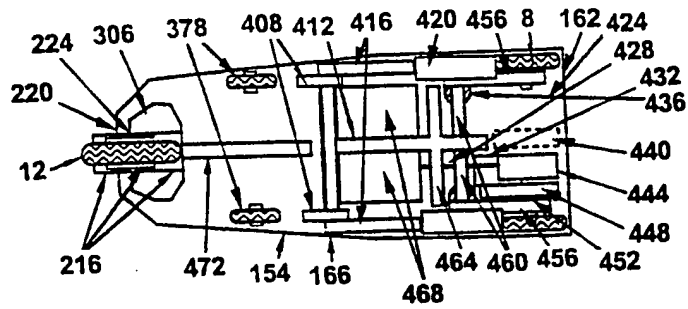


FIG. 23

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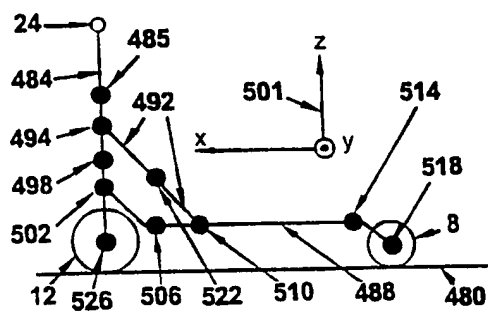


FIG. 24

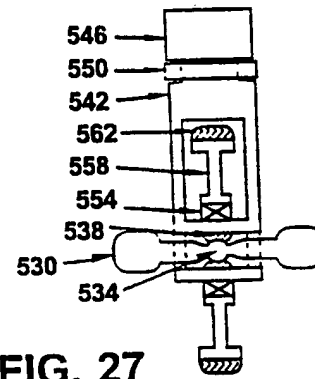


FIG. 27

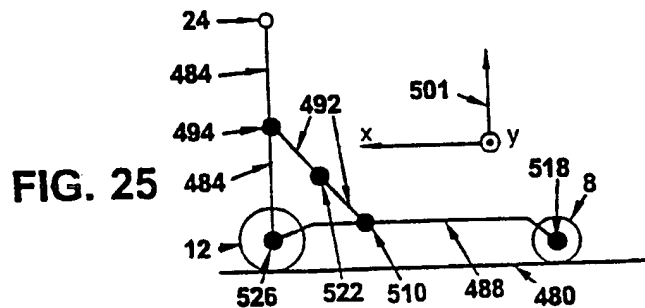


FIG. 25

TABLE 1. Bearing configurations relative to Figure 24*

Name	Lateral Tilt	526	502	506	514	498	494	522	510
A	Y	y	z	R	R	y	N	N	N
B	Y	y	z	R	x	y	N	N	N
C	N	y	z	R	R	y	N	N	N
D	Y	y	z	x	R	R	y,z	S	x,y
E	Y	y	z	x	R	y	y,z	S	x,y
F	Y	y	z	x	R	R	y,z	y	x,y
G	Y	y	x,y,z	R	R	R	y,z	S	x,y
H	Y	y	x,y,z	R	R	R	y,z	y	x,y
I*	Y	x,y,z	-	-	-	-	y,z	S	x,y
J*	Y	x,y,z	-	-	-	-	y,z	y	x,y

* indicates Figure 25 instead.

FIG. 26

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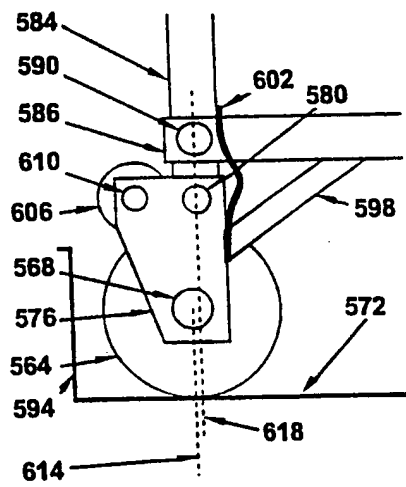


FIG. 28a

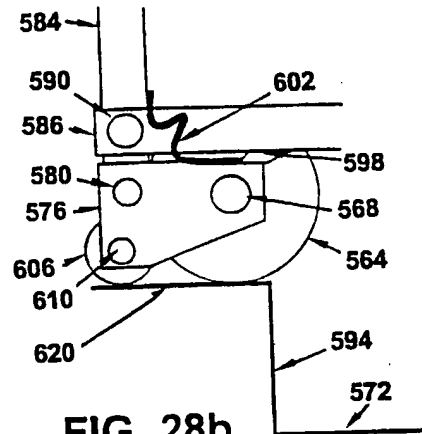


FIG. 28b

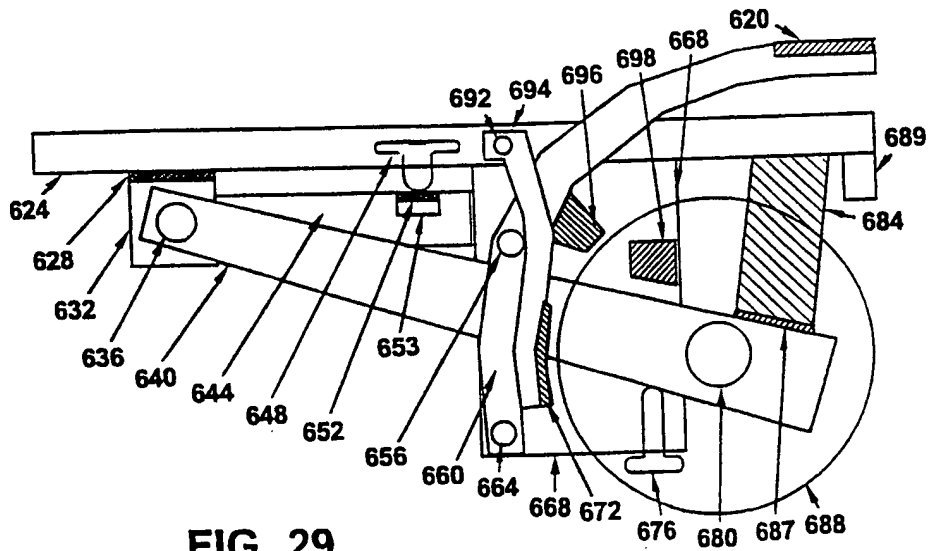
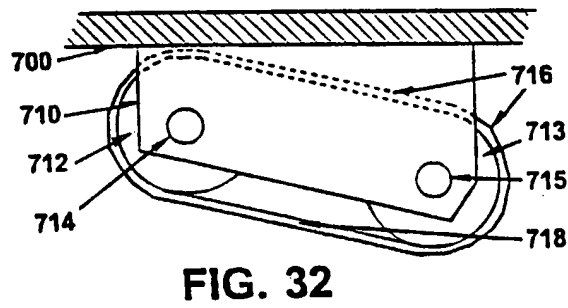
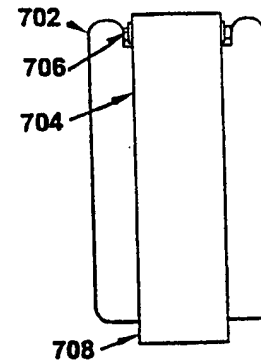
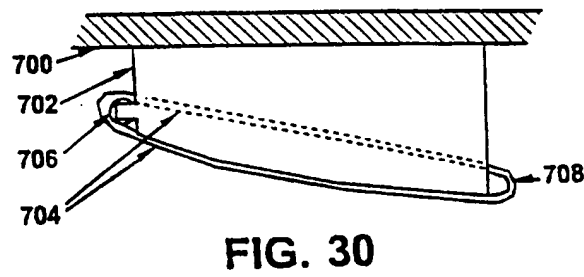


FIG. 29

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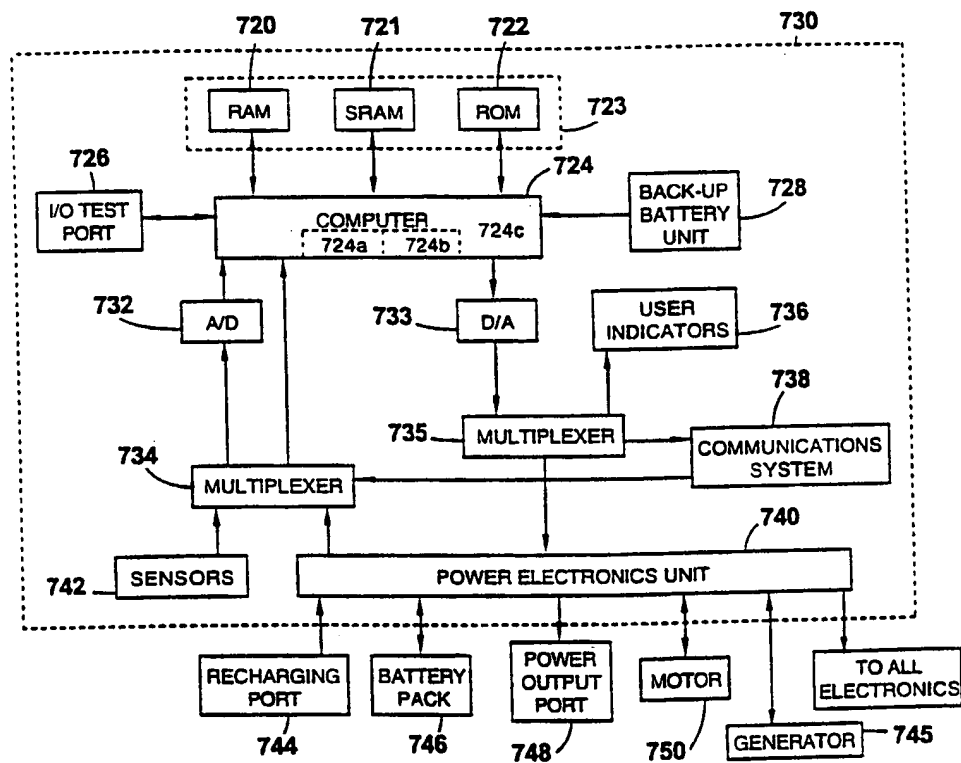


FIG. 33

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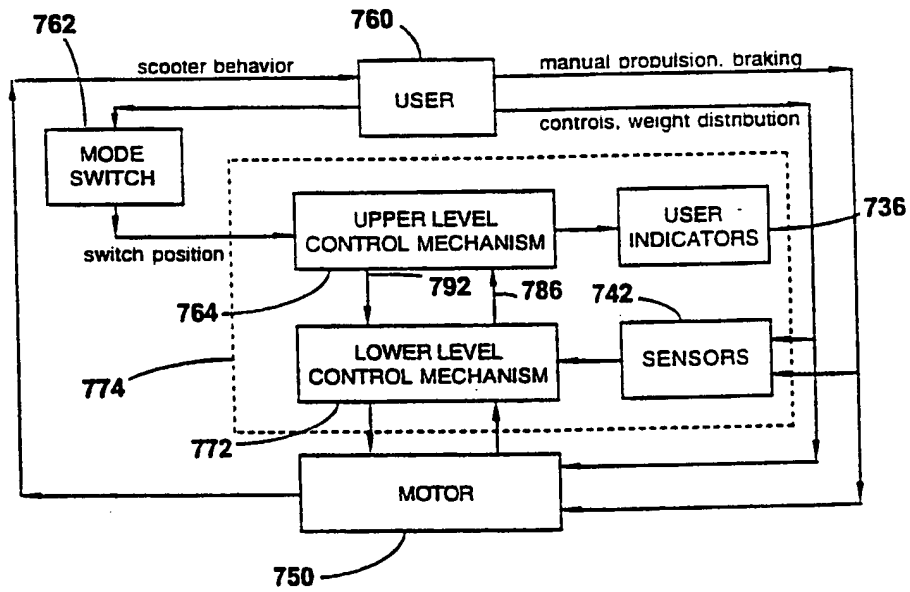


FIG. 34

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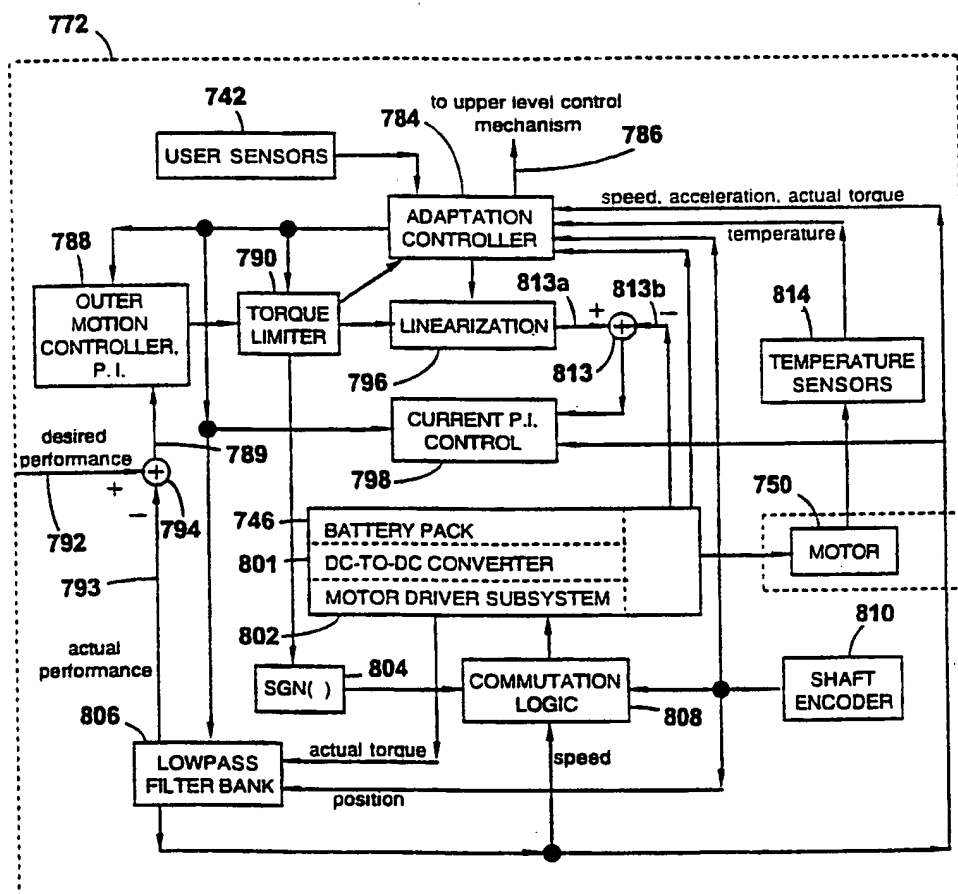


FIG. 35

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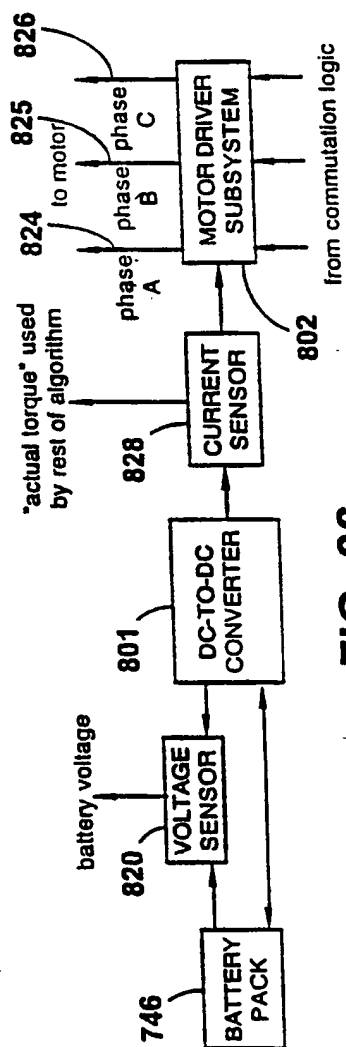
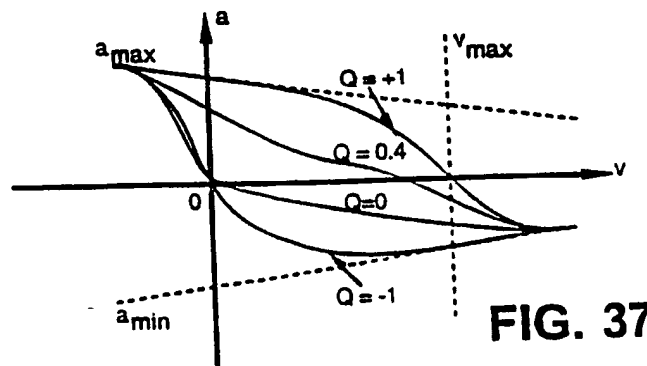


FIG. 36

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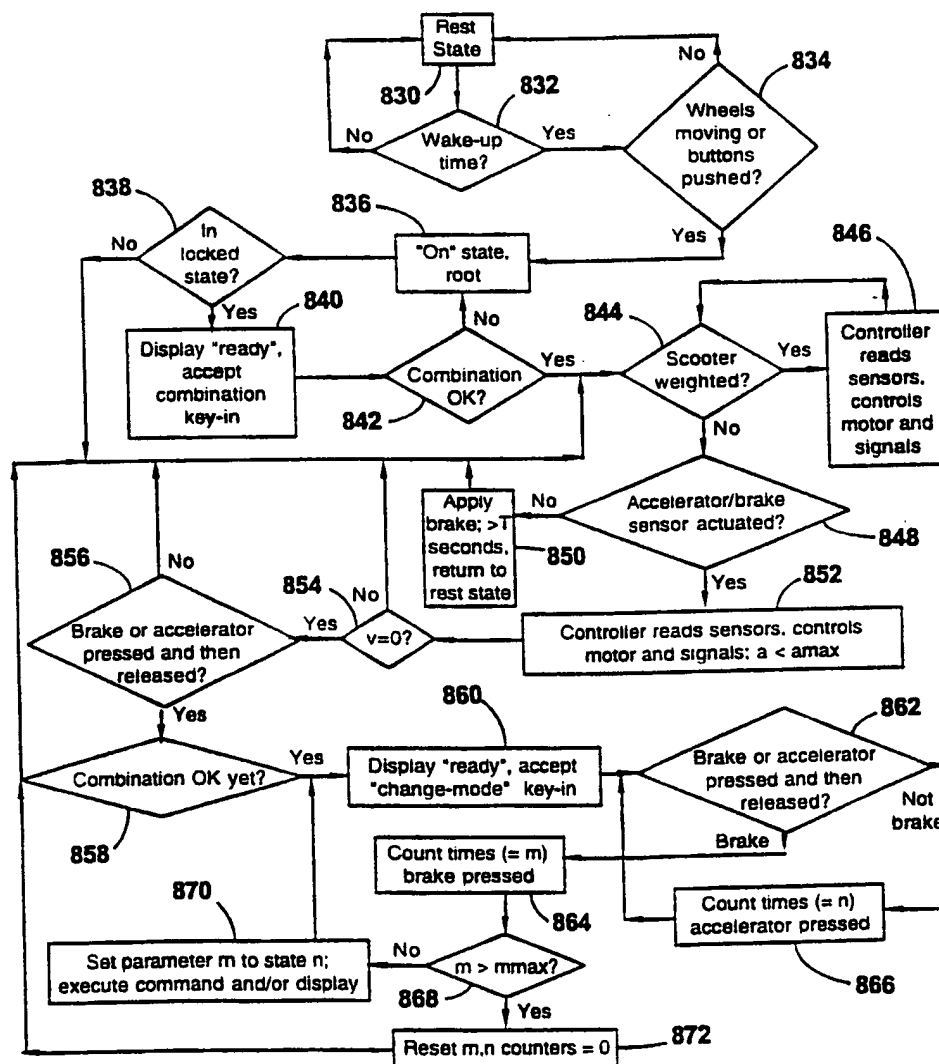


FIG. 38

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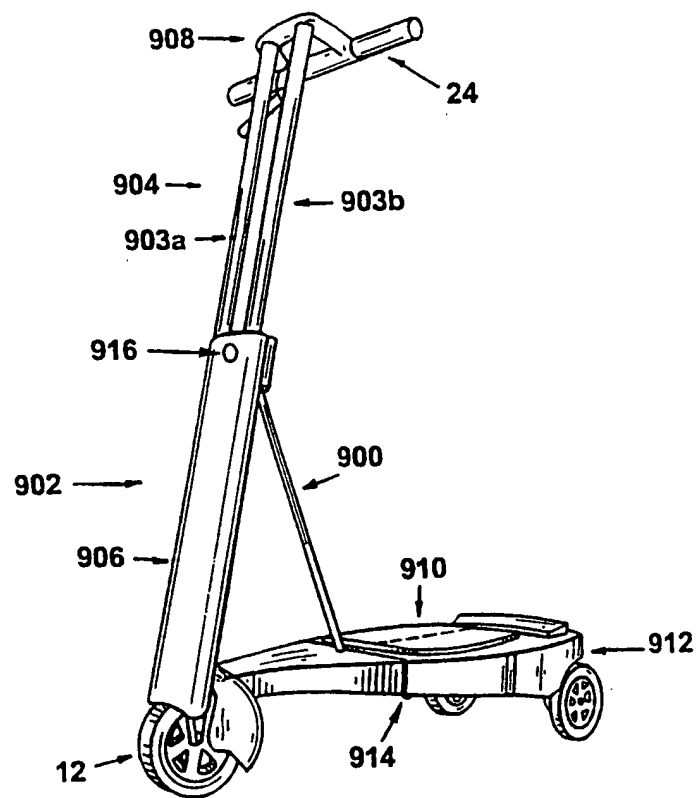


FIG. 39

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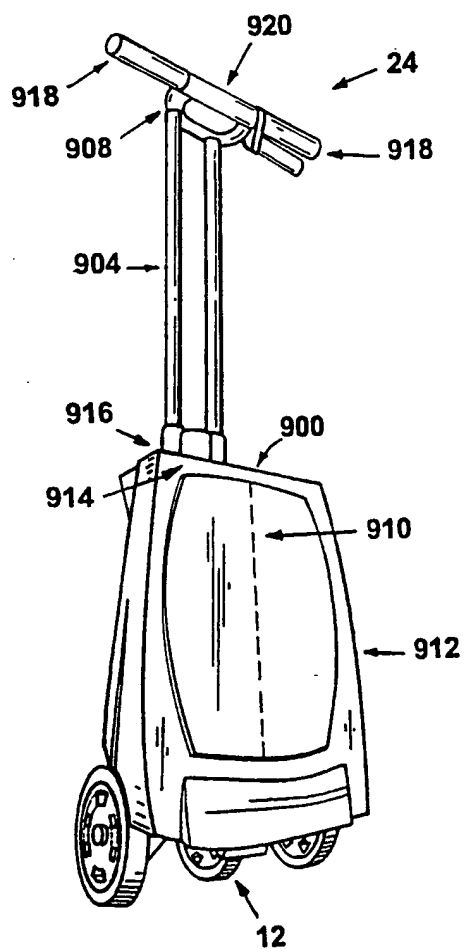


FIG. 40

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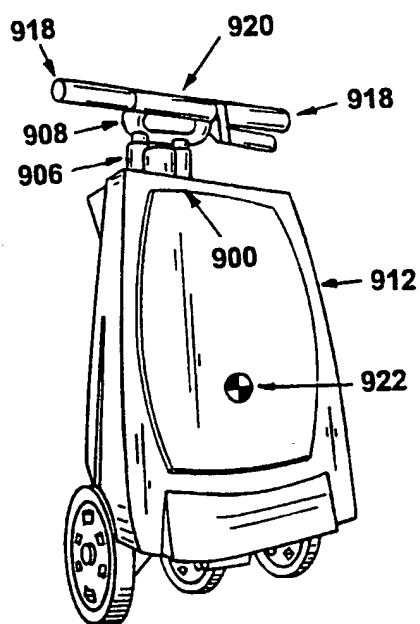


FIG. 41

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